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[THIRD SERIES.]

ART. I.—*Upon the relation which the former Orbits of those Meteorites that are in our collections, and that were seen to fall, had to the Earth's Orbit;* by H. A. NEWTON.

[Read before the National Academy of Sciences, April 19, 1888.]

MY studies have led me to the following three propositions:

1. The meteorites which we have in our cabinets and which were seen to fall were originally (as a class, and with a very small number of exceptions), moving about the sun in orbits that had inclinations less than 90°; that is, their motions were direct, not retrograde.

2. The reason why we have only this class of stones in our collections is not one wholly or even mainly dependent on the habits of men; nor on the times when men are out of doors; nor on the places where men live; nor on any other principle of selection acting at or after the arrival of the stones at the ground. Either the stones which are moving in the solar system across the earth's orbit move in general in direct orbits; or else for some reason the stones which move in retrograde orbits do not in general come through the air to the ground in solid form.

3. The perihelion distances of nearly all the orbits in which these stones moved were not less than 0·5 nor more than 1·0, the earth's radius vector being unity.

The first and third propositions are limited strictly by their terms to the meteorites from stone-falls actually witnessed, and also represented by specimens in some one or more of existing collections. The investigations that have led to them have been limited to the same stone-falls This is not because any line of separation is suspected to exist astronomically between the stone-furnishing and the detonating meteors, or even between them and the shooting stars, but because, for manifest reasons, any facts established about these stones have a greater value than similar facts about meteors from which no stones have been secured.

About 265 observed falls are represented by specimens in existing collections. The history of these falls I have searched out with no little pains, so far as the material for such history could be found in books accessible to me. Every direct statement and every indirect indication which I have obtained about the paths of these meteors through the air have been carefully considered, and their meaning and value duly estimated. The determination of the path of a stone-furnishing meteor through the air is greatly aided by the fact that we know at once one point of the trajectory, viz: the point where the stone strikes the ground. To this fact may usually be added another, viz: that some of the observations are by persons near the place of fall, and hence their statements of direction, so far as we may trust them, have peculiar significance. In individual cases it will be found that not much reliance can be placed upon the asserted direction of the meteor's motion. But when the results are all collated there is such a general agreement in support of the first and third propositions set forth above that I am very confident that they are true.

The orbit of a meteoroid about the sun is wholly given when we know these three things, the time when it enters the air, the direction of its motion, and the velocity. The velocity cannot be easily measured directly. But the connection between meteors and comets will be assumed as fully proven. The velocity of the meteoroids (neglecting the increase due to the earth's attraction), ought then to be that of the comets, at the same distance from the sun. The greatest cometary velocity at the distance unity is $\sqrt{2}$, the earth's velocity being unity. The smallest velocity for any known comet is that of Encke's comet, which at the earth's mean distance from the sun is 1·244. It seems safe, therefore, to assume that the meteorites we are considering had velocities relative to the sun not greater than 1·414, nor less than 1·244.

The direction of a meteor's motion through the air is to be determined solely by the evidence of observers of the stone-fall. This evidence needs to be carefully collated, especially

when statements apparently conflict. A judicial temper of mind must be preserved in estimating the meaning of the statements, lest the evidence be twisted to the support of some preconceived notion. Knowing the danger, I have tried to keep my own mind free from bias.

We need not know the *exact* day, but we must know the time of day of the stone-fall, else the direction through the air cannot be used. This throws out about one-fifth of the total number of falls named above,—there being no statement of the time of day of the fall attainable. There are left 210 different cases available for use. For 94 of these there is no reliable statement of the direction of the motion of the meteor. We know only the day and the hour. Even this, however, is of some value, since we know that the meteor must have been moving downward at the place of fall; that is, from some point of the heavens then above its horizon. For 116 stone-falls the direction of the motion of the meteor is more or less definitely indicated by the statements of observers, or by the statements of those who have inquired into and reported the facts of the falls.

We may then divide the observed stone-falls into three groups which will be separately considered: (*a*), 116 falls for which we have statements as to the direction of the path through the air; (*b*), 94 falls of which we know the time of day; (*c*), 50 or more falls of which the history is too scanty to give the time of day.

There is frequent occasion to speak of two points on the celestial sphere for which the English language has no good names. These are the point from which a body is moving, and the point to which a body is moving. These two points are opposed to each other, as north is to south, east to west, zenith to nadir. The words *quit* and *goal* will be used to denote these two points. The *earth's quit* is that point of the ecliptic from which the earth is moving, the *earth's goal* that point to which the earth is moving; the one being about 90° ahead of the sun in the ecliptic, the other 90° behind it. A *meteor's quit* is that point of the heavens from which the meteor is moving; its *goal* that point of the heavens to which it is moving. The motion may be that relative to the earth, in which case the point of the celestial sphere from which it is moving is the meteor's *relative quit.* Thus the relative quit of a meteor when it is entering the air must be above the horizon of the place of entrance, inasmuch as the meteor must be moving downward. If a meteoroid's motion be corrected for the earth's motion the direction of its absolute motion about the sun is obtained, and then the two points of the celestial sphere from which and to which the meteoroid is moving are its *absolute quit* and its *absolute goal.*

The observations have been treated graphically. They do not demand nor do they admit of greater accuracy in methods of discussion than can be used in graphic processes, and these processes have many advantages over numerical computations. A stereographic projection of two hemispheres was prepared and printed, upon which there were three sets of coördinate lines from three sets of poles. The three sets of points were the angles of triquadrantal triangles. Thus the lines were drawn to represent at intervals of 10° the distances and directions from the poles P, P, S, E, and G, Q, (fig. 1, p. 7). In the engraved figure these coördinate lines are omitted. The common diameter of the two hemispheres ESE was made to represent the ecliptic, and the sun was placed at the center or, at the edge of one of the hemispheres. The point P would then be the poles of the ecliptic, and if S be the place of the sun the earth's quit will be Q, and the earth's goal G.

To treat any single meteor a large celestial globe was first set for the time and place of the fall. Upon the globe the celestial latitude and longitude of the zenith and of the west-point were then measured The day of the year gave the sun's longitude. The zenith and west-point could then be marked upon the chart, after which it was easy to draw the circles representing the meridian and the prime vertical. The stereographic projection was peculiarly advantageous in this work as all circles are represented by circles, and angles are conserved in the projection. The effort was then made to mark upon the chart the meteor's relative quit as accurately as the observations permit, or rather to describe an area within which the quit was probably or certainly located.

Some of the 116 meteorite quits have been heretofore fairly well determined by other persons, or they can be so determined. This is the case with the meteors of Agram, Weston, Orgeuil, Pultusk, Iowa, Rochester, Esthervillle, Krähenberg, Khairpur, Vendome, etc. For other cases we are able by comparing the various statements of observers to locate approximately the relative quit. But for a considerable number of the falls we have to be content with the simple statement that the stones came from the north, or from the northeast, or from the south-southeast, or from some other similarly defined direction. When this has been the case I have taken a point 20° above the horizon in the direction indicated, and considering this as the center of an area of considerable size within which the quit was probably located, have treated the point itself as the meteor's quit.

These observations of direction in some cases will be in error, or will be perverted in reporting, as every one who has tried to reconcile numerous accounts of a meteor has unpleas-

antly learned. But when the statements have come from persons who saw the stones come down, they are usually of much more value than similar reports about ordinary meteors. In any case when the reports are single they must be taken for what they are worth. I have plotted them as given.

In several notable instances where there are full accounts I have not been able to accept the conclusions heretofore arrived at as to the direction of the meteor's path. Thus, Dr. Bowditch made the path of the Weston meteor to be from north to south and parallel to the horizon. I make it to have moved from a point N. 40° W., 35° high. The Cold-Bokkeveld meteor was described by Sir Thomas Maclear as moving from the W.N.W. It apparently moved in the opposite direction; that is, from the E.S.E. The l'Aigle meteor was described by M. Biot as moving from the S.S.E., whereas it is well nigh certain that it came from the N.W. In like manner the Stannern meteorite was assumed by von Schreibers to have come from the N.N.W., whereas there are reasons of great weight for believing that it came from the opposite direction. I may add that these and other like changes are not made under any pressure or bias to prove my propositions. In fact three of the four changes just named make the evidence for my conclusions weaker instead of stronger.

In the treatment of the observations several quantities have been neglected as not large enough to be comparable with the probable errors of the observations themselves. Thus the effect of the earth's attraction in changing the direction of motion, or what has been called the *zenithal attraction* of the quit, has been allowed for only in a general way. So the earth's quit and goal are treated as being exactly 90° from the sun; or, in other words, the earth's orbit has been treated as a circle. In like manner the motion of the place of fall due to the earth's rotation on its axis has not been taken account of.

Having located upon the chart the meteor's relative quit we have next to construct its absolute quit. This evidently lies on the great circle joining the relative quit to Q (fig. 1), which, when the sun is at S is represented on the chart by a straight line through Q, together with its corresponding line through G. When the absolute velocity of the meteoroid in its motion about the sun is given, the place on this circle of the absolute quit can be determined by combining by the parallelogram of velocities the motions of the earth and of the meteoroid. The following table is an abstract of a larger one used in this reduction, and is constructed for the limiting velocities 1·414 and 1·244:

Table showing the distances from the earth's quit to the absolute quit of a meteoroid for different distances from the earth's quit to the relative quit of the meteoroid.

Distance from Q to relative quit.	Distance from Q to absolute quit. $v=1{\cdot}414$.	$v=1{\cdot}244$.
30°	9°·3	6°·3
60	22·1	15·8
90	45·0	36·5
120	82·1	75·8
150	129·3	126·3
180	180·0	180·0

In the following constructions the maximum velocity of the meteoroid has been used. When the meteoroid's relative quit is known as a point the absolute quit is at once constructed. If, however, we have an area within which the relative quit is probably located we may mark off with equal facility points on the boundaries of the area within which the absolute quit is probably located. If the former area is a circle the latter will be an oval. The center of the circle does not correspond exactly to the center of the oval, but by applying a correction to the table the center of the oval absolute-quit area can be directly constructed from the center of the circular relative-quit area.

In figure 1 I have given in a single diagram constructed on a stereographic projection, the results for 116 stone-falls. The best determinations which the accounts admit of for the meteor's direction were first made out. Then the center of the probable quit area in each case was assumed to be the actual quit. When only the quarter of the heavens from which the stones came is stated the center of probable area was taken 20° above the horizon. Interpreted thus, the stars in figure 1 represent the places of the 116 absolute quits relatively to the place of the sun, S, and to that of the earth's quit and goal, Q and G.

Let us denote any one of these quits (or stars), by the letter q. The elements of the orbit in which the corresponding stone was formerly moving can be easily obtained from the projection. The earth's longitude on the day of fall is the longitude of the node. The angle qSQ is the inclination of the orbit to the ecliptic, and its amount is at once read off on the projection. The orbit has been assumed to have been a parabola. Hence, twice the complement of qS was the angular distance of the stone from its perihelion. If $q\mathrm{S} > 90°$, the perihelion had not been reached; if $q\mathrm{S} < 90$, the perihelion, had been passed. The perihelion distance was $\mathrm{Sin}^2 q\mathrm{S}$. If, however, it be assumed that the orbit was a long ellipse of given major axis, the place of the absolute quit, q, moves somewhat nearer to Q

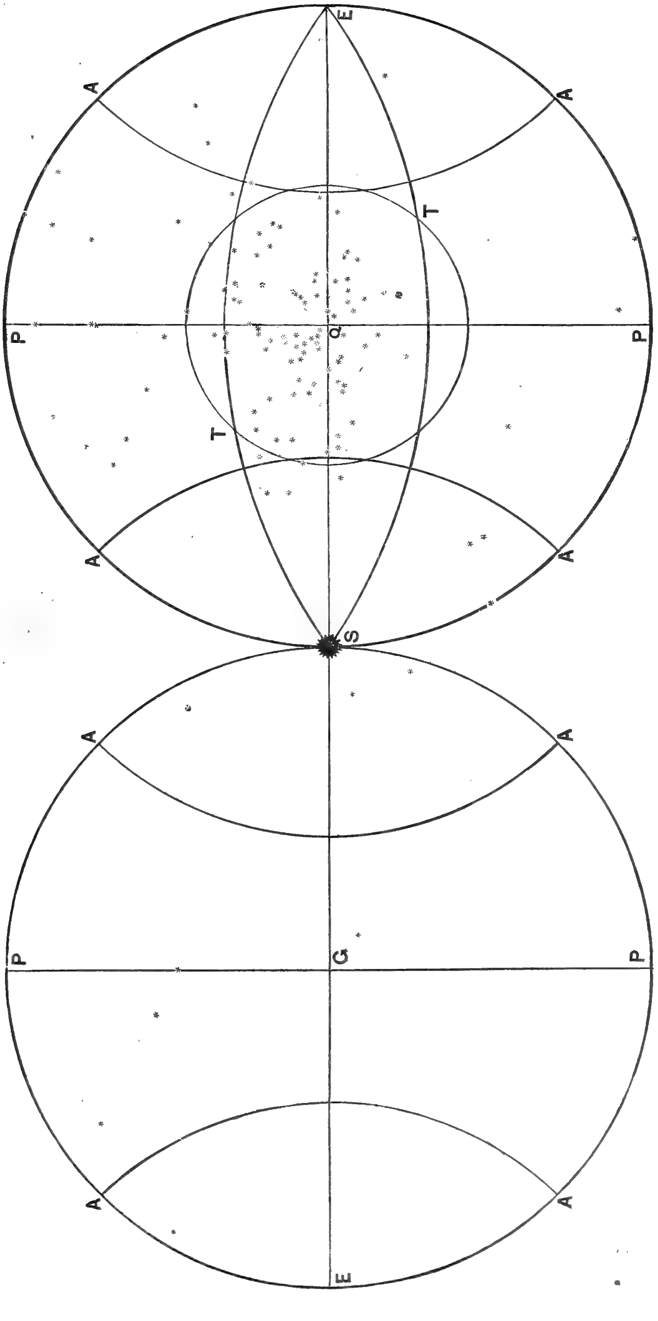


FIGURE 1.—Showing the distribution of 116 meteorite quits relatively to the sun's place and to the earth's quit.

along the line qQ, the angle in the plane of the orbit from perihelion was a little more than twice the complement of qS, and the perihelion distance somewhat less than $\mathrm{Sin}^2 qS$. But all these quantities are easily computed in terms of the assumed major axis. With a semi-major axis as large as 5 the change in figure 1 would not be so considerable as to modify any conclusions we can deduce from the grouping of the stars.

The most noticeable fact revealed by the figure is the clustering of the stars about the point Q. All but 7 of the 116 meteor quits are in the Q hemisphere; that is, had orbits whose inclinations were less than 90°. One hundred and nine followed the earth, seven met it. Again the two lines STE are drawn to represent circles inclined 35° to the ecliptic. More than two-thirds of the meteor quits lie between these two lines; hence, over two-thirds of the orbits were inclined less than 35° to the ecliptic, the motion being direct.

It should be said that this clustering of the points near Q is somewhat exaggerated in the figure by the nature of the stereographic projection. The scale of distances near Q differs from that near the circumference. But this does not affect the distribution between the hemispheres.

It has been assumed that certain centers of quit areas were themselves the quits. Can the condensation of the quits near Q have been caused in any way by this assumption? Or, is it possible that general errors of observation, or inaccuracy of reporting, could have been the cause? To answer this question let us suppose that there had existed a law that led to condensation of the relative quits in any manner whatever. The effect of the errors of observing or reporting, and also the effect of the assumption above stated, would be toward scattering these relative quits over the heavens more equably, and thus masking the law. Then when the relative quits thus unduly scattered are reduced to absolute quits there might be as a result a tendency towards condensation near Q. If, however, we draw the circle TT, enclosing those absolute quits whose relative quits are in the hemisphere next Q, the general tendency of the errors in question would be towards equalizing the number of absolute quits within to those without the circle TT. Now, the number of stars is nearly twice as great within as without the circle. The condensation about Q, shown in figure 1, exists therefore in spite of, and not in consequence of, these errors. With a good deal of confidence do I conclude that these 116 meteors were, as a class and with probably a very few exceptions, before coming into the air following the earth in its orbit about the sun.

Another fact of great interest is also shown by the grouping of the points in figure 1. In general these stones did not go

in their orbits very near to the sun. Assuming that the orbits were parabolas we have for all the stones whose perihelion distances were less than one-half, $\mathrm{Sin}^2 q\mathrm{S} < \frac{1}{2}$. If there be drawn circles, AA, AA, 45° from S and from E, then will all the stones whose absolute quits were in the central zone, APPAAA which is bounded by the circles AA, have perihelion distances greater than one-half and less than unity. Of these there are 103 out of a total of 116. If the same orbits are assumed to have had semi-major axes equal to 5, then the circles AA would have to be drawn a fraction of one degree farther from S and from E to serve as the limiting curve to orbits whose perihelion distances exceed one-half.

It appears from figure 1 that these 116 stones were, with a few exceptions, following the earth in their orbit about the sun. This could happen from either one or more of three possible causes:

Firstly, that nearly all the stones in the solar system are moving in direct orbits, very few in retrograde orbits;—

Or, secondly, that stones moving in retrograde orbits for some reason, as for example their great relative velocity, may not have been able to pass through the air and to reach the ground in solid form;—

Or, thirdly, that stones moving in such retrograde orbits, and coming through the air, may be falling while men sleep, or for some like reason may fail to be found. In other words, the effective cause may work above the air, in the air, or below the air.

Let us assume, as an hypothesis, that neither of the first two are the true causes. In that case we should have the stones moving in every direction as they cross the earth's orbit. There should be about as many orbits having retrograde motions as direct motions. Hence the absolute quits of all stones coming into and hence, by hypothesis, coming through the air, should be symmetrically distributed in their longitudes relative to the sun. At least there should be as many absolute quits in the G-hemisphere as in the Q-hemisphere (figure 1). Take account now of the earth's motion and locate the relative quits. All these stones whose absolute quits lie outside of the circle TT will have their relative quits in the G-hemisphere. Upon the hypothesis of parabolic orbits and of an equable distribution of the absolute quits over the celestial sphere the number of relative quits in the G-hemisphere should be to those in the Q-hemisphere as $1+\cos\frac{\pi}{4} : 1-\cos\frac{\pi}{4}$, or as $17:3$. The relative quits should then be *very much* more numerous in the G-hemisphere than in the Q-hemisphere.

Furthermore, suppose that the heavens visible at a given time

and place, are divided by a vertical circle into two halves; and suppose that this vertical circle is at right angles to the plane containing the zenith and the earth's quit and goal. That half of the visible heavens that lies towards the earth's goal may be called the goal-half, the other half may be called the quit-half of the visible heavens. In any given period there should evidently be, under the several hypotheses stated, many more stones coming into the air and reaching the ground directed from the goal-half than there should be directed from the quit-half of the visible heavens. Still further, since this proposition applies to any epoch whatever, we may apply it to 116 periods covering the times of the 116 stone-falls, that is, to the 116 stone-falls themselves. Many more of these should (under the hypotheses stated) have come from the goal-half than from the quit-half of the visible heavens.

If, then, the relative quit of each of these 116 stones is supposed to be carried around in azimuth 180°, the altitude being unchanged, the 116 distances from each new place of the quit to the earth's quit for the epoch of the fall should, in the average, be decidedly less than the corresponding 116 distances from the actual relative quits to the earth's quit. This should hold true (under the hypotheses stated) no matter what causes below the air may have occasioned the selection of the 116 epochs. The fact that more persons are abroad in the evening hours from 6^h to 10^h P. M., than in the corresponding morning hours, 2^h to 6^h A. M., may well cause that more stones should be secured in the evening than in the morning hours. In the evening hours the earth's quit is above the horizon; in the morning hours the earth's goal. It might easily be that we should for this reason get more stones of direct than of retrograde motions. But the above criterion is entirely independent of any such principle of selection of the epochs. A change of the azimuth of the quits through 180° should cause a larger number of them (under the hypothesis stated) to approach the earth's quit than to recede from it.

I have marked off upon the working sheets the position 180° in azimuth from each of 115 relative quits, the altitude being unchanged, and measured the several distances from the earth's quit. (One fall, Nedagolla, was unavailable.) The following is the result. In 44 cases the meteor's quit by the change approaches the earth's quit; in 70 cases it approaches the earth's goal; in one it remains unchanged. That is, instead of a very large majority of the quits moving towards the earth's quit we have nearly two-thirds of them moving the other way. In the reversed position, moreover, we should have had 38 absolute quits in the G-hemisphere instead of 7. These numbers show very decidedly that the hypotheses made above are not

true. The principle of selection is not *entirely* below the air, and the numbers testify so markedly against that hypothesis that I feel warranted in adding that the cause is *mainly* either above the air, or in the air.

Between the first and second causes named the materials used for the present discussion do not furnish a *positive* critical test. But if, as I believe, the Stannern stone came from the south, we have at least one instance of stones coming into the air with a velocity of nearly, or quite, 45 miles a second and reaching the ground in solid form. About 25 of the quits in figure 1 imply velocities of not less than 25 miles a second on entering the air. Large velocities do not seem to be entirely fatal to the integrity of the meteorites. I believe that the first cause was the dominant one rather than the second, yet for a crucial test of the two causes, if one can be found, we must look to a class of facts other than those we have been considering.

We are now in position to consider the other 94 stone-falls. In figure 2, the construction of which is similar to that of figure 1, the stars mark the zenith points for each time and place of the 94 falls. A grouping is at once noticeable. They are nearly all in the northern hemisphere, since the observing peoples live there. Those stars in the hemisphere of which S is the pole, that is between the two lines PP and PP, are evidently daylight stone falls, since S is above the horizon for each case. These constitute about seven-eighths of the whole number. The reason for this predominance is manifest. In the night men see the fireball or the train, whereas in the day the first intimation of the stone-fall is usually the hearing of the detonation two or three minutes after the fireball has disappeared. Hence, daylight stone-falls are those whose directions are less likely to be observed, and these 94 falls are the ones of which the directions are unknown.

It will also be seen that there are nearly twice as many in the Q-hemisphere as in the G-hemisphere; that is, there are nearly twice as many that fell when the earth's quit was above the horizon as there were when the earth's goal was above the horizon. In general, the former were afternoon stone-falls, the latter forenoon stone-falls. Now the habits of the urban population have not much to do with these daylight meteors, for the fireballs were not seen. The accounts come from the country, where the stones in general have fallen, and about as many people are there abroad in the forenoon as in the afternoon. If stones came to the ground as often from retrograde as from direct orbits we ought apparently to have had very many more zeniths in the G-hemisphere than in the Q-hemisphere. The contrary being the fact of experience we may rea-

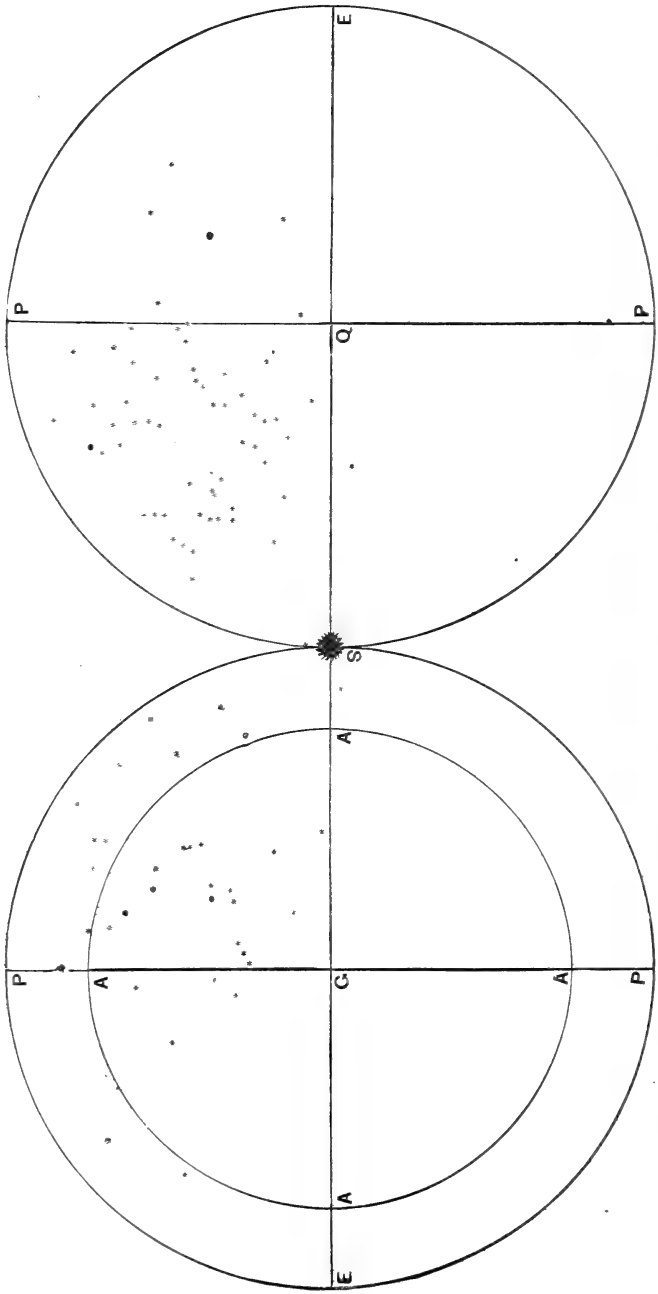


FIGURE 2.—Showing relatively to the sun's place, the zeniths for the time and place of 94 stone-falls.

sonably say that the 94 stone-falls, about which we know comparatively little, seem decidedly to follow the same laws as the 116 falls about which we know so much more.

This conclusion is greatly strengthened if we take account of the effect of the earth's attraction in carrying the meteor's quit toward the zenith. Any stone must be moving downward when it enters the air. But the earth's attraction must change the direction of its motion during the approach to the earth. Hence the region of the heavens from which a stone can approach the earth is not bounded by the actual horizon, but by a curve which may be treated as a depressed horizon. This depression of the horizon is far greater toward the quit than toward the goal side of the horizon. The maximum depression for a stone moving in a parabolic orbit is about 17°. It hence follows that when the zenith is more than 73° and less than 90° from G, both the points G and Q are above the depressed horizon, and therefore that the 14 falls whose zeniths are between these limits, that is, are between the circles AA and PEPS, figure 2, should be left out of the count. The corresponding region on the Q-hemisphere is less than one degree in breadth, and contains one zenith point. We have left only 20 falls when the earth's goal alone was above the depressed horizon to be compared with 59 falls when the earth's quit alone was above the depressed horizon.

Of the 50 observed falls constituting the third group, of which the hour of fall is not stated, very few particulars other than the fact of fall are known. Although we are left without the power of saying that they indicate the same law as the other 210 falls, we find at the same time no reason to suspect the contrary. It is not unreasonable to assume that the well-observed stone-falls are good representations of the whole group, and to affirm the three propositions with which I set out as true, in general, not only for the 210 stone-falls of the first two groups, but for the whole 260 stone-falls which are represented by stones in our cabinets, and in which the stones were seen or known to fall.

It also seems a natural and proper corollary to these propositions (unless it shall appear that stones meeting the earth are destroyed in the air), that the larger meteorites moving in our solar system are allied much more closely with the group of comets of short period than with the comets whose orbits are nearly parabolic. All the known comets of shorter periods than 33 years move about the sun in direct orbits that have moderate inclinations to the ecliptic. On the contrary, of the nearly parabolic cometic orbits that are known only a small proportion of the whole number have small inclinations with direct motion.

It also follows that in future reductions of these stone-fall observations it will be better to assume that the velocity of the stone in its orbit was not that velocity which corresponds to a parabolic orbit, but that which corresponds to the mean orbit of the comets of short period. The largeness of the perihelion distances has an evident bearing also upon the idea that these stones form the fuel of the sun.

The presentation of the argument here made has been incomplete in that the details of the investigation of individual stonefalls has been entirely omitted. Some of the determinations of the paths are, I think, as complete as I can hope to make them. But others must be regarded as provisional, since I hope to secure respecting them additional data. I hope at some future time to give a complete discussion of all these observed stone-falls. In the past I have been greatly indebted to friends for aid in collecting accounts of the falls, and I heartily thank them therefor. I shall be very grateful also in the future for unpublished observations of the stone-falls, as well as for observations that have been so published as not to be likely to have attracted attention. I bespeak the kindly aid of any who have made or have collected such observations.

Art. II.—*History of Changes in the Mt. Loa Craters;* by James D. Dana. With Plates I, II, III.

[Continued from page 289; and also from xxxiii, 433, xxxiv, 81, 349, xxxv, 15, 181.]

Supplement to the History of Kilauea.—Since the debris-cones of Halema'uma'u, the great lava-lake of Kilauea, have a constitution and history unlike anything thus far reported from other volcanic regions, I add to the previous notes the following from a recent letter of Mr. J. H. Maby, of the Volcano House, dated March 8th. Mr. Maby writes that the cone has been rising since August, of 1887, until now the summit is "on a line with the outside walls of the crater, looking from the Volcano House." No additions have been made to the exterior, but instead, the eastern side (which Plate 5 in the last volume, from a photograph, showed to be in process of separation from the rest) "has slipped down a little and changed considerably its shape." Moreover the bottom or floor of the Great Lake with its lavas, is now within 40 or 50 feet of the top, which implies a rise of 30 or 40 feet in the same interval. The fires have been very active, and are now visible, from the house, on the *east* side of the cone; and the lavas on that side have flowed over into the deserted basin of New Lake, filling its lower portion. The lake on the west side of the cone has also much increased in size, being now nearly 300 feet in diameter; and it has thereby encroached on the doomed cone.

II. MOKUAWEOWEO, THE SUMMIT CRATER OF MT. LOA.

Maps.—A map of the island of Hawaii, reduced from the Government map, is here introduced (Plate 1) for the better illustration of the facts and discussions beyond.* It shows the topographic simplicity of the island—a fact not expressed in most of the small published maps, which generally (like that of the eleventh volume of the new Encyclopedia Brittanica) put in mountain ranges or ridges that do not exist. The map will enable the reader to appreciate the relative position of Kilauea and the Mt. Loa crater, their relative heights, the absence of water-courses from all of the mountain slopes except a small windward region; the large size of the valleys of the Kohala Mountains to the north; the positions of the great lava streams of 1840 to 1887; the routes of the roads (mostly bridle paths); the two routes to Kilauea, one of thirty-one miles on horseback from Hilo, the other of about half this distance, from Keauhou, the upper half a good carriage road; and also the districts into which the island is divided, and the positions of the principal villages.

The present form of the summit crater, Mokuaweoweo, is shown on the map by J. M. Alexander, Plate 2, reduced from the results of his survey. The height of the highest point, given on it, 13,675 feet, differs eighty-five feet from Wilkes's determination of the same point in 1841.

The *history* of the summit crater is mostly a history of the results of its eruptions, for few facts have been observed about the action *within* the crater. It has excited attention when an eruption has been in progress: but the chief outflows have begun below the summit and the source of the outflow is usually the only place reached. Still there is much to be gathered from the reported facts. My personal investigations have been confined to the base of the mountain, and the review beyond is hence almost solely from the accounts of others.

History of the Eruptions from 1832 to 1888.

1832, *June* 20.—On the 20th of June, 1832, according to Rev. Joseph Goodrich, lavas were discharged from several vents about the summit. The fires continued to be visible for two or three weeks, and were seen from Lahaina, 100 miles to the northwest. Nothing is known of any large discharge of lavas, and no mention is made of accompanying earthquakes.

*The Government map, as stated upon it, is only a preliminary map, part of the survey being still incomplete.

† Goodrich, this Journ., xxv, 201, 1834, letter of Nov. 17, 1832.

The outbreak of Kilauea in 1832 occurred about the same time, but possibly a few months later (xxxiii, 445, 1887 and xxxv, 15, 1888).

1834, *January* 29th.—Mr. David Douglas, the naturalist, who was the first to ascend Mt. Loa, describes the crater, in his Journal,* as having great chasms in the bottom that he could not fathom "with a good glass and the air clear of smoke:" and says further: that "the depth to the bottom on the east side was by an accurate measurement with a line and plummet, 1270 feet;" that the southern part of the crater, "where the outlet of the lava had evidently been, must have enjoyed a long period of repose." He mentions hearing light hissing sounds from fissures in the summit that might "perhaps be owing to some great internal fire escaping." He adds, "There is little to arrest the eye of the naturalist over the great portion of this huge dome, which is a gigantic mass of slag, scoriæ and ashes."

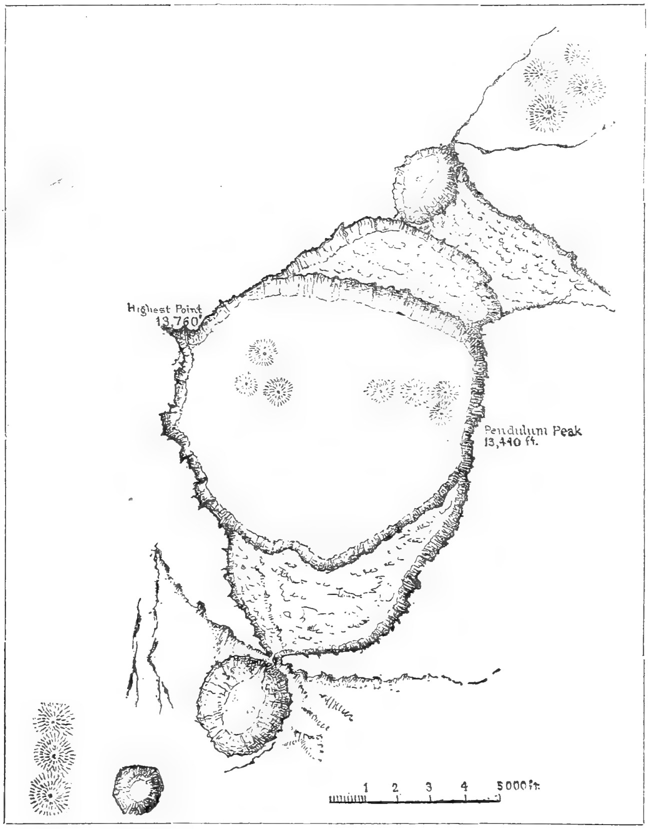
1841, *January.*—Captain Wilkes was at the summit during the latter part of January, 1841.† Lieutenant Eld, by taking angles from the bottom of the crater, made the western wall 784 feet high, and the eastern, 470 feet. The only sign of activity was the escape of steam and sulphur gases from many deep fissures over the bottom, especially on the west side. The fissures had generally a N.N.E–S.S.W. direction. There was one cinder or scoria cone at the bottom, according to Dr. Judd, toward the southwest side, having a height of about 200 feet. Other steam cracks were observed outside about the pit crater of the south-southwest end; and one, which they "designated the great steam-crack, led from the top of the mountain a long distance down its sides toward the south;" and a great depth was indicated by the reverberations from a block of lava which was dropped into it. Small driblets of lava were observed along some of these fissures; indicating feeble ejections at the very summit. In Wilkes's map, as shown in the outline copy on the next page, seven small cones are faintly represented on the bottom of the crater, although the descriptions speak of only one.

1843, *January.*—In January of 1843 began one of the great outflows. It continued for about six weeks. Clouds above on the 9th made the first announcement to the people of the

* Companion of the Bot. Mag., ii, 175, 1836, and in a letter to Capt. Sabine, dated May 3, 1834, Journ. Geogr. Soc., iv, 333, 1834. See this Jour., xxxiii, 436, 437, 1887, on the letter to Dr. Hooker and the evidence against it.

† Narrative of the Exped., iv, 152, 156, 159. The descriptions of the crater are from descents made into it by Dr. Judd of Honolulu (on p. 152) and Lieut. Henry Eld (on p. 156). Wilkes's map has its longer diameter, through some mistake, north-and-south in direction.

islands. During the following night, according to Dr. L. Andrews,* a brilliant light appeared at the summit, looking, as Mr. Coan states, like "a small beacon fire."† In a week



The Summit crater, after Wilkes, January, 1841.

the light disappeared. In the mean time the lavas had commenced their discharge. Mr. Coan ascended to the source, about 13,000 feet up, and found two large craters near together, very deep and active. The source given on the map is at least 2000 feet lower. The stream of lava flowed toward Mt. Kea, but gave off a westward branch, toward Hualalai, near its source. At the base of Mt. Kea, a branch went northward toward Waimea, and another eastward toward Hilo. Mr.

* Andrews, Missionary Herald, xxxix, 381, letter of Feb. 6, 1843.

† Coan, ibid., xxxix, 463, letter of Feb. 20, 1843; xl, 44, letter of April 5; this Journal, II, xxvii, 411, 1859; Life in Hawaii, 1882, p. 270.

Coan states that over the crusted surface of the stream were many steaming openings 20 to 50 feet broad, down which he saw the lavas rushing along the tunnel-like way, "with awful speed, some fifty feet below us;" large stones thrown on the surface were carried "instantly out of sight before sinking into the stream." The action was much diminished in six weeks, but was "still somewhat vehement at one or two points."

Mr. Andrews states that during the progress of the eruption Mr. Wilcox visited Kilauea and found no signs of sympathy.

1849, *May.*—A brief notice of brilliant fires at the summit crater in the month of May, 1849, is contained in a letter of Mr. Coan's, dated January, 1851. He says, that the light was first noticed *after* the extraordinary activity in Kilauea. "I cannot say that they were coincident." For two or three weeks, a brilliant and lofty column of light was seen over the mountain. There is no reported evidence as to any surface outflow of lavas, and none of an earthquake.*

1851, *Aug.* 8.—A short flow commenced at this date a few miles west of the summit.† From Hilo, a column of clouds was seen by day, which was fiery by reflection at night. The eruption continued, as far as could be seen from Hilo, only three or four days. No earthquake was reported.

Mr. Wm. T. Brigham in 1864 visited the flow, and states ‡ that the outbreak of 1851 occurred about 1000 feet below the summit "or 200 feet below the bottom of the crater." He estimated the length of the stream at "ten miles and the average breadth less than a mile," and the volume, "160 million cubic yards of lava." "The greater part is the pahoehoe, although some aa occurs." The course was westward, near that of an old stream toward Kealakekua.

1852, *Feb.* 17.—One of the greatest of the Mt. Loa eruptions began on the 17th, only six months after the eruption of 1851, as if its supplement. The place of outbreak, according to Mr. Coan,§ was on the north side of the summit, near that of 1843. When first seen, the light looked like "a planet just setting" over the top of the mountain. In a few minutes the whole summit was brilliant, and Hilo also; and a stream of lava commenced its flow down the mountain. Forty hours later the fires had apparently become extinct.

After three days, on the 20th, the chief flow began at a point on the eastern side about 10,000 feet above the sea-level, near

* Coan, this Journal, II, xii, 82, 1851. letter of January, 1851.

† Coan, this Journal, II, xiii, 395, 1852, letter of October 1, 1851; and D. D. Baldwin, ibid., p. 299, from "Polynesian" of Aug. 23, 1851.

‡ Volcanoes of the Hawaiian Islands, 4to, 1868, p. 389.

§ Coan, this Jour. II, xiv, 105, 219, 1852; Life in Hawaii, p. 279.

the terminus of a line of fissures leading down from the place of the first outbreak. *The escaping lavas rose at first in a lofty fountain*, and then flowed eastward for twenty miles. On the 27th, Mr. Coan reached the place of the fountain approaching it on the windward side within 200 feet. He found the lavas playing, as he states, to a height of 400 to 500 and 700 feet, by angular measurement, in ever-varying forms of towers, pyramids and spires, and with variations also in colors from white heat at base to red above and then to grayish red and gray.

Great volumes of lava were ascending and descending, not intermittently but continuously; and the "surging, roaring, booming" sounds were almost deafening, but without earthquake from beginning to end. Ashes and capillary glass fell in the streets of Hilo. The stream stopped about ten miles from the village. The grand eruption was in blast only twenty days. All this time Kilauea was quiet.

In July, Mr. Coan ascended again to the crater or place of discharge* and found the fires extinct. He says, a kind of "pumice" was abundant and widely scattered; "we found it ten miles from the crater, and it grew more and more abundant till we reached the cone, where it covered the whole region to a depth of five or ten feet."

An ascent to the active fires was made early in March by Mr. H. Kinney† and Mr. Fuller. Mr. Kinney, speaking of the sounds from the cataract of liquid lavas, says: "its deep unearthly roar, which we began to hear early on the day before, waxed louder and louder as we drew nearer the action, until it resembled the roar of the ocean's billows when driven by the force of a hurricane against a rock-bound coast, or like the deafening roar of Niagara." This description attests to the fountain-like character of the discharge; for such sounds do not come from flowing lavas unattended by earthquake phenomena. Mr. Kinney made the height of the jets 400 to 800 feet. He reports also, that the heat created terrific whirlwinds which stalked about like so many sentinels, bidding defiance to the daring visitor.

Mr. Fuller states,‡ that from careful calculations made, "after deliberate discussion with Mr. Kinney," "some of which," he says, "have been confirmed by a somewhat accurate measurement by Mr. Lyman of Hilo," the diameter of the crater from which the fountain rose was about 1000 feet; height of the crater, 100 to 150 feet; height of the fountain,

* Coan, ibid., xv, 63, 1853.

† H. Kinney, this Journal, II, xiv, 257, 1852, from the "Pacific" of San Francisco of June 19, the letter dated Waiohinu, Hawaii, April 19, 1852.

‡ Fuller, this Journal, xiv, p. 258, 1852, letter dated Waiohinu, March, 28.

200 to 700 feet, and rarely below 300 feet; diameter of the fountain, 100 to 300 feet, "and rarely perhaps reaching 400 feet." The jet of fire sometimes shot up into a tapering gothic spire of 700 feet, then rose in a grand mass 300 feet in diameter, but varied at top with points and jets like the ornaments of gothic architecture. He adds that to appreciate the most terrific element in the sublime composition you should stand at the foot of a Niagara, or on a tempest-lashed shore; for "the force necessary to raise 200,000 to 500,000 tons of lava at once into the air would not be silent in its operation." The lava stream is stated to have a depth, in some places, of 200 or 300 feet.

1855, *Aug.* 11.—During the evening of August 11, a glowing point of light was seen at a height of 12,000 feet on the northeast slope of the mountain.* The light rapidly extended, and it soon became evident that a lava-stream was on its way down the mountain. No earthquake had announced the eruption.

Mr. Coan ascertained, through his excursions, that a line of fissures extended from near the summit for five miles down the northeast side to the place of outbreak, along which there were cones of volcanic scoria and sand 100 feet or so high, that had been thrown up at the points of greatest activity. Descending the mountain, the cones became lower and less frequent, and were the ragged jaws of orifices through which the stream of lava was visible.

The place of outflow was a crater formed over a fissure two to thirty yards wide. The lava flowed in a continuous stream down slopes of all angles from less than one degree to verticality. The course was eastward like that of 1852, and it finally stopped within five miles of Hilo.

Mr. Coan describes the tunnels in the lava stream, and speaks of the lavas seen through openings, as moving with great velocity—"estimated to be 40 miles an hour." Some of the steaming openings were 30 to 200 feet long, and the flowing lavas were 50 to 100 feet below. But the progress of the front of the stream, where were obstructions of trees, jungles, depressions, etc., was "slow—say one mile a week." He observes that owing to the cooling, and the partial damming thereby along the front, the hardened upper stratum was raised by the descending stream into numerous tumuli of various forms and sizes as if by pressure from above, which became cones or domes, and let out lavas to flow over the surface and add to the

* Coan, this Journal, II, xxi, 144, 139, 1856, letters of Sept. 27 and Oct. 15, 1855; ibid., p. 237, letter of Nov. 15, 1855; ibid., xxii, 240, letters of March 7, 1856; ibid., xxiii, 435, 1857, letter of Oct. 22, 1856; Life in Hawaii, p. 289.

thickness; that "upgushings" also occurred through fissures; and that thus layer was added to layer, increasing the thickness from a few feet to 50 or 100, and also retarding the progress of the stream. One dome on the stream was 100 feet high and 300 in diameter; and through the fissured top and sides the liquid lavas were visible, and easily reached by the pole he had for measuring the thickness of the cap—2 to 5 feet. These effects were especially great where the slope was very small. Pressure of the lavas above, and gases or vapors from the burning of trees and other vegetable matter buried by the lavas, are made the causes of the uneven surface of the lava stream.

The stream, in addition, became widened by the lateral outgushings, divided into a number of channels, and shifted to the right or left. After flowing freely for a while, the stream often suddenly cooled and hardened along the front and remained for several days inactive; "at length, immense areas of the solidified lava, four, five, or six miles above the extremity, are again in motion, cones are uncapped, domes crack, hills and ridges of scoria move, immense slabs of lava are raised vertically or tilted in every direction."

On the 22d of October, 1856, the stream was within five miles of the sea-coast north of Hilo, still pushing out and spreading itself. Mr. Coan says that the lavas were even then flowing in the tunnel-ways from the place of outbreak to the lower extremity although no fires were seen—evidently an opinion rather than a direct observation. He argues for the absence of fissures beneath the stream for the supply of lava, from the absence of steaming vents and cones. After 15 months, in November, the fires ceased action. The stream includes many square miles of aa and immense fields of pahoehoe.

1859, *Jan.* 23.—Another great eruption began at this date. Prof. R. C. Haskell (of a party visiting the eruption consisting also of Prof. Alexander and President Beckwith) reports* that "smoke" was seen over the summit from Waimea by Mr. Lyons of that place on the 23d. In the evening, lavas were ejected, and the light was bright enough at Hilo, 35 miles east, to read fine print. "No earthquake was felt in any part of the island." But dead fish, apparently parboiled, were found in the sea to the northwestward, both east of Molokai and between Molokai and Oahu.

* Haskell, this Journal, xxviii, 66, 284, 1859, (the latter from letter of June 22); xxix, 301, 1860, letter of Nov. 5. There are shorter reports by Editor of Commercial Advertiser of Oahu and Rev. L. Lyons, ibid, xxvii, 412, 1859; and Coan, ibid. xxvii, 415, letter of February 2, 1859, and xxix, 302, letter of Nov. 25, 1859. W. L. Green, "Vestiges of the Molton Globe," 1887, pp. 163, 270, 280.

The stream flowed northwestward by the northeast foot of Hualalai and reached the sea on the 31st of January at Wainanalii, a dozen miles south of Kawaihae, a distance in all of 33 miles in eight days. The chief source was probably about 10,500 feet above the sea level. Above this point for four miles, a fissure, two inches to two feet wide, descends the mountain from which some lavas escaped. Several cinder cones stand along the line of fissures, and two of them near its extremity. Half a mile farther down the outflow began.

The lavas, "white hot" as they escaped, were thrown at once into a fountain, as at the 1852 eruption, the height of which, according to Mr. Vaudrey, who happened to be on the mountain at the outbreak, was 300 or 400 feet.

On the 9th day of February, the issuing lavas were "at a white heat and apparently as liquid as water." The report says that the stream below dashed along in cataracts and rapids at such a rate that "the eye could scarcely follow it." For eight to ten miles there was a succession of cascades and rapids, some of them a consequence of obstructions met on the way and others due to the obstructions which the stream made. The lava flowed more gracefully than water and with great velocity, following the surface beneath, rising as it rose, and turning abruptly, with the outside of the stream higher than the inside, the mobility being perfect.

Both *pahoehoe* and *aa* were formed. The aa portions are described by Prof. Haskell as produced by deep lava streams; streams flowing sluggishly where the slopes are small; which become dammed up in front by the cooling, by the breaking up of the cooled barrier and crust, and by the rolling over and over of the stream. Often at the end of the aa stream no liquid lava can be seen, and the only motion is the rolling of the jagged rocks of all sizes down the front of the embankment. Sometimes it breaks through the embankment, and flows on "carrying jagged rocks of all sizes on its back, which look like hills walking;" then it gets clogged again, with finally a repetition of the process of breaking up and piling.

The stream after reaching the seashore continued flowing into the sea till after the 25th of November. The surface of the stream was of black hardened lavas; but at the sea-border, the liquid lavas ran out at a red heat, having flowed under cover, Prof. Haskell states, for at least 25 miles, if not from the source.

According to Mr. W. L. Green the column of vapor that rose from the orifice or crater, along side of which his tent was pitched, was 500 feet wide and 10,000 feet high. He says, "From the whole interior of the crater rose the great illuminated column of smoke perpendicularly, and then at a great

height in the atmosphere it spread out on all sides." It continued for many weeks, but ceased before the flow was ended. The lava appeared to have broken out at the intersection of two fissures. Over the surface in the vicinity, there was a thick deposit of "pumice" or "glass-foam." The top of the mountain at the time was covered with snow—a source of percolating water. While he was near the stream, on the plain between Loa, Kea and Hualalai, loud explosions were heard all night long, like the reports of heavy cannon."

Mr. Green also states, from his observations, that at the seashore, it ran over a low shelf about ten feet high and perhaps 500 or 600 feet wide and fell into the sea where the water was 20 or 30 feet deep. "It came from under the crust in great red-hot flattened spheroidal masses, having something the appearance of moderately thick porridge as it is poured from a saucepan—the spheroidal masses perhaps 10 to 15 feet wide and 4 to 6 feet deep" "There was no steam, vapor or gas whatever to be seen coming from the lava until it went under water. Indeed the first contact of the red-hot spheroids did not seem to produce a particle of steam, and it was only when each had gone under water and become partially cooled off that a puff of steam rose above the water"—"an effect due to the spheroidal state of the water against the red-hot surface."

No sympathy was exhibited by Kilauea. Mr. Coan says "we have occasional earthquakes: two in February, one in July and two in November of the current year (1859)."

In June, according to Prof. Haskell, there was no action in the summit crater.

1864, *August* 5.—Mr. W. T. Brigham found the summit crater, at this date,* without any signs of action excepting some "steam issuing from the northern bank." There were two cones at bottom, about 200 feet high, near the east side. He also observes that in various places over the great plain about the crater there "were large irregular masses of a solid reddish clinkstone, much used for stone axes," and speaks of the "hard compact graystone of the summit and walls."

1865, *December 30th*.—Light was seen "at the very summit," on the night of the 30th of December.† It continued, with variations in intensity, sometimes very brilliant, at others faint or gone, for four months, or until the last of April, or perhaps into May. Mr. Richardson, proprietor of the Volcano House, reported the occasional escape of steam, but no outflow of lava is known to have occurred. "The falls of snow

* Memoir, p. 384.

† Coan, this Journal, II, xli, 424, 1866, letter of Feb. 27, 1866; and xliii, 264, 1867, letter of August 31, 1866.

on the mountains this winter have been frequent and heavy, extending almost to their bases." No earthquakes were reported. "As it was winter, no one ascended the mountain." In May, a great increase of activity began in Kilauea.

1868, *March 27th.*—On March 27th, Friday, many slight earthquakes were felt in Kau, southern Hawaii, and in Kona, the southwestern district. On the 28th they were more energetic and frequent, and extended east to Hilo, and northward through Kona. Mr. T. D. Paris, of Kealakekua, south Kona, reports* that on the morning of Friday, fire and great columns of "smoke" were seen at the summit; and on Saturday the 28th, the fires were visible from Hilo, according to Mr. Coan.† Mr. F. S. Lyman reports, from Kau, that the first outbreak was a little to the southwest of the summit; that others followed, and soon the lavas were seen in four streams running down the mountain in a southerly and easterly direction. By Sunday (the 30th) the line of smoke had advanced about 15 miles on a line toward Captain Brown's house in Kahuku; but the light of the summit had disappeared; it was not seen at Hilo after the 28th. During this time the earthquakes became still more violent and destructive, and almost continuous. On Thursday, April 2d, at 4 P. M., occurred "the terrible shock," destroying houses and life, making fissures of great length and depth, dislodging rocks and half a mile in breadth of marshy earth from the mountain side of Kapapala, to the destruction of a native village, besides raising earthquake waves on the southern coast, that swept away the villages of Punaluu, Ninole, Kawaa and Honuapo. The position of the land-slide is shown on the map of Hawaii, Plate I. It was also violent to the eastward in Hilo, the only stone building being thrown down, and furniture in other houses; but so light on Oahu, 200 miles to the westward, that most of the inhabitants of Honolulu were unaware of it, those in stone houses being almost the only persons that felt it.

On the 7th of April, the lava escaped from a wide fissure in the district of Kahuku. Along this fissure, in the course of a mile, the escaping lavas were thrown into four fountains, which were playing on the 10th, when the place was visited by Mr. H. M. Whitney, of Honolulu. According to this writer's description, the fountains rose to a height of 500 to 600 feet, along the line of the fissure for a mile. The lavas were "blood-red, yet as fluid as water." Sometimes two of the fountains joined, and then all four were united. At one time they subsided for a few minutes, and then burst out

* Paris, this Journal, II, xlvi, 107, 1868.

† Coan, ibid., p. 106; F. S. Lyman, ibid., p. 109; H. M. Whitney, ibid., p. 112.

again and went to a height of 1000 feet. Large stones and rocks were thrown up, some weighing 100 tons; and so many that they seemed to fill the air. The lava of the fountains is stated to have had a rotation "to the south." Below the fountains, the lava flowed in a rapid stream to the sea, making a descent of 2000 feet and reaching the shore in two hours. The rate of flow is stated to have been 10 to 25 miles an hour.* A cinder or tufa cone was made at the place of discharge into the sea, which was first an island, and afterward became joined to the land by the flowing lava. The eruption ceased in the night between the 11th and 12th, after only five days' activity. The lava is mostly pahoehoe, with some areas of aa, and extremely chrysolitic. At the crack above the main outburst, the lava which escaped was light brownish scoria, which was drifted by the winds, along with much capillary glass. The season was one of unusual rains over the mountain.

Prof. C. H. Hitchcock examined the region of eruption in June of 1885, both above and below the extremity of the pali (precipice) represented on the map by the west side of the lava-stream. He states the following facts in a letter, of May 30, 1888, to the author. The fissure whence the lavas of 1868 flowed "is in exact continuation of the pali, up the mountain. I traced it fully three miles. For much of the way it makes a narrow cañon 40 or 50 feet wide at the maximum, and so deep that it is dangerous to explore it. In the lower part heat was still evident. The fissure is most prominent where the lava is in greatest amount. Its borders have the smoothed appearance that would result from an outflow of lava over its edge. The very uppermost point reached we estimated, from our aneroid, to be 3100 feet above Mr. Jones's ranch near the north end of the pali. There is no cone at that point, as there is at the sources of the 1855 and 1881 flows which I also visited. Every fact harmonizes with the view of a rent three miles long, allowing the accumulated lava to discharge in one or two days' time, instead of oozing out of a single small orifice for months. The connection of the fissure with the pali shows clearly the existence of a fissure along its whole length, which has been the seat of eruptions in ages past. This Kahuku flow was analogous to that of Kilauea in 1840.

1870, *January* 1.—During the first two weeks of January, much "steam and smoke" arose from the summit crater.† In the course of the preceding month, Judge Hitchcock, of Hilo, with others, visited this crater and found much escaping steam,

* Pacific Commercial Advertiser of May 9th, 1868. See also W. L. Green's Vestiges of a Molten Globe, pp. 294–303. Mr. Green does not intimate that Mr. Whitney's description is exaggerated.

† Coan, this Journal, xlix, 393, 1870, letter of Jan. 24, 1870.

but no visible fires. Slight shocks of earthquakes often occurred, sometimes one, two or three a day.

1870.—Mr. Severance (as I learn from Rev. E. P. Baker, of Hilo) was at the summit crater in 1870, and found no action there.

1872, *August* 10.—On the night of the 10th of August, says Mr. Coan,* "a lofty pillar of light," 2000 feet high—which means lighted vapors of this height—stood over the summit crater, with varying brilliancy, indicating active fires within. The crater was "in full blast on the 27th," and continued so into September. On the 23d of August a tidal wave was felt on the coast at Hilo, the waters during a calm rising four feet, and in a second wave, six minutes later, three feet, and diminishing for about fourteen oscillations. It may have been part of the Mt. Loa disturbance; but Kilauea also was unusually active over its interior. No earthquake is reported. The Pacific Commercial Advertiser of Sept. 21st† reports on an ascent to the summit made just before this date. Near the southwest corner of the crater there was a fountain of lava about 75 feet in diameter, playing, it is stated, to a height of 500 feet. The basin from which it rose covered about a third of the bottom, and was at the top of a low cone made by the falling lavas.

1873, *January 6th and 7th.*—On the 6th of January, the action at the summit, as seen from Hilo, was "marvelously brilliant," the lighted vapors visible at night rising thousands of feet above the summit.‡ There was evidence, apparently, of active ebullition or a playing fountain; and this conclusion is favored by the fact that the herdsmen of Reed and Richardson's ranch, at Ainapo, on the eastern slope (4200 feet above the sea), stated that the mountain was "constantly quivering, like a boiling pot." The action suddenly ceased, without any known outflow; the time of ending the display is not mentioned. Kilauea had been very active for months. No earthquake is spoken of, and no sympathy with Kilauea implied.

1873, 1874. *April* 20, 1873, *to autumn of* 1874.—The brilliant summit display of January was followed on April 20th, three months later, by a return to activity, or to a degree of activity that was visible from Hilo. Mr. Coan observes that the lofty columns of light above the summit at

* Coan, this Journal, III, iv, 406, 1872, letter of Aug. 27, 1872, and v, 476, 1873, letter of Feb. 14, 1873.

† This Journal, iv, 331, and 407, 408, 1872.

‡ Coan, this Journal, III, v, 476, 1873, letter of Feb. 14, 1873; vii, 516, 1874; xiv, 68, 1877. In the first of these notices, the date given is Jan. 27th; in the others, Jan. 6th and 7th.

night, and of clouds by day were proof of violent ebullition within the crater.

On the 6th of January, 1874, Mr. Coan writes* that, for nine months, the action within the great crater has not remitted. "The great marvel is its duration," without any outside results. There appears to have been a turn of special brilliancy in January. On the following October (the 6th), he says† the action has continued "for eighteen months, and the most of the time it has been violent. But of late it has become more quiet, and there is a prospect that it will soon cease." He adds, "we have had few earthquakes during the year, and these have been feeble." "Kilauea all this time was unusually active;" but no sympathy with Mt. Loa was observed.

1873, *June* 6.—It is of great importance to the history that we happen to have trustworthy reports with regard to the condition of the summit crater on one of the days during this era of prolonged activity. And as it was a day of feeble summit light as seen from below, it affords data for an estimate as to the condition during times of greater brilliancy. The explorer, Miss Bird,‡ was at the summit on the 6th of June, and describes well the condition of the crater. For the most part its floor was an area of solid black lava; but at one end (the southwest?) there was "a fountain of yellow fire" 150 feet broad, which played in several united but independent jets to a height of 150 to 300 feet. The party for the two days preceding had been under the impression that the fires had faded out; and yet this fire-fountain was all the time in action. When within two miles of the crater monitions of the activity were apparent in a distant vibrating roar; and on reaching the crater edge, the roar was like that of an ocean, rising and falling "like the thunder-music of windward Hawaii"—a comparison used also by Mr. Kinney in describing the eruption of 1852. (p. 19.) At night the lake was the most part at white heat, and its surface was agitated with waves of white hot lava about the fountain at the center. Through the rest of the vast crater the projecting ledges were thrown into bold relief by the reflected light, and by numerous dashes and lines of fire from apertures and crevices. Occasional detonations were heard, but no shakings except the tremors from the throw and fall of the lavas. At one time the jets, after long playing at a height of 300 feet, suddenly became quite low, and for a few seconds there were "cones of fire wallowing in a sea of light;" a description that not only reads well, but I feel sure is to the life, like the

* Coan, this Journal, III, vii, 516, 1874, letter of Jan. 6.

† Coan, ibid., viii, 467, 1874, letter of Oct. 6, 1874; and xiv, 68, 1877, letter of March 17, 1877.

‡ Six months in the Sandwich Islands, by Isabella L. Bird, London, 1876.

most of Miss Bird's pictures; then, "with a roar like the sound of gathering waters, nearly the whole surface of the lake was lifted up by the action of some powerful internal force, and its whole radiant mass rose three times in one glorious upward burst, to a height, as estimated by the surrounding cliffs, of 600 feet." "After this the fountain played as before." (p. 272). "In one place heavy white vapor blew off powerful jets from the edge of the lake and elsewhere, and there were frequent jets and ebullitions; but there was not a trace of vapor over the burning lake itself."

In "The Vestiges of the Molten Globe," (p. 166) Mr. W. L. Green, with whom Miss Bird made her ascent, gives confirmatory facts. He makes the height of the fountain generally 300 to 400 feet, as estimated from the known depth of the crater; and occasionally some spires shot up, he observes, to a greater altitude. He adds: "Among the varied forms of the fountain there were the low rounded dome, a spire at center, with a fountain either side in the form of a wheat sheaf, and one great wheat-sheaf." Besides a dull roar, there was "the metallic clink" from the fall of masses of lava of the fountain which were cooled in the air; these cooled fragments formed a light falling veil over the dazzling fountain, and descending into the lake outside of the jets, making a scum over its surface. Only a light vapor was seen over the playing fountain.

Early in *August*, 1873, Dr. O. B. Adams ascended Mt. Loa, at a time when the light at the summit was unusually brilliant. He found the fountain playing, he says, to a height of 200 to 500 feet, and "assuming all the forms of a grand fountain of water."*

1875, *January.*—Mr. W. L. Green mentions the occurrence of summit action at this time for a month, in his tabular statement of eruptions, and says nothing of one in August of this year, to which date Mr. Coan refers the 1875 eruption. The report of the Challenger sustains Mr. Coan's statement, but does not positively set aside that of Mr. Green.

1875, *August.*—Mr. Coan says:† I think it was on the 11th of August that the summit crater was again in brilliant action. The action continued, as appeared in the view from Hilo, for one week, and without any observed evidence of an outflow.

In the first half of August, the day not stated, a party from the Challenger Expedition visited Kilauea. As reported in volume I of the Scientific Results of the Expedition, p. 766, "a globular cloud" was seen over the summit of Mt. Loa, which

* Hawaiian Gazette, Sept. 3, 1873.

† Coan, this Journ. xiv, 68, 1877, letter of March 17, 1877.

was "perpetually reformed by condensation," and had "a brilliant orange glow at night, looking as if a fire were raging in the distance."*

1876, *February* 13.—Another grand display from the summit crater, but of short duration. No outflow is reported.†

1877, *February* 14.—The display of light on the 14th, says Mr. Coan,‡ was "most glorious." The columns of illuminated steam rose "with fearful speed to a height of 14,000 to 17,000 feet, and then spread out into a vast fiery cloud, looking at night as if the heavens were on fire." The brilliancy continued only for ten days.

No outflow is positively known to have occurred, but it is probable that a submarine discharge took place off western Hawaii. The steamer brought passengers from Honolulu to visit the mountain, but returned as the fire had disappeared. But before the vessel was fairly out of sight of land, "a remarkable bubbling was seen in the sea about three miles south of Kealakekua, a mile from the shore," and steam and scoria were thrown up.

Mr. H. M. Whitney states that "blocks of lava two feet square came up from below, striking and jarring the boats"; and "nearly all the pieces on reaching the surface were red-hot;" "as soon as they became cold they sunk. This eruption took place on the 24th of February, the day the light disappeared from the summit.§

On the land new fissures were opened up the mountain that had a westward course toward the place of submarine disturbance. An earthquake is reported as having been felt in the fissured region, but not at Kealakekua. A heavy tidal or earthquake wave occurred about this time along the coast of Kona.

[1877, *May* 10*th*.—A destructive earthquake wave was felt at the Hawaiian Islands on May 10th, 1877, which rose at Hilo to a height of 36 feet. But it was of South American origin, where there were heavy earth-shocks, and not of Hawaiian.]

1880, *May* 1.—Early in the morning of May 1st, a light was seen at or near the summit, which soon after became intense so as to illuminate Hilo at night. It indicated violent activity, and led to an expectation of a great eruption. But clouds obscured the mountain for a few days, and when they disappeared, the light was gone.‖ On the 3d and 4th of May, flocks of Pele's hair and light particles of volcanic dust, drifted by the wind,

* See also Moseley's "Notes by a Naturalist of the Challenger," London, 1879, p. 500.

† Coan, this Journ., xiv, 68, 1877, letter of March 17, 1877. ‡ Ibid.

§ Hawaiian Gazette, Feb. 28, 1877.

‖ Coan, this Journ., III, xx, 7, letter of May 3–6, 1880.

fell over Hilo. According to reports from Puna and Kau, the action had not ceased by May 6th. Mr. Brigham reports* that his guide was at the summit at the time and saw boiling lava in the south crater; and that the top of the jets were visible to the native while he was lying down some distance from the brink; which would make the height of the jets, Mr. Brigham says, 1,000 feet. As the depth of the crater was not over 800 feet, his estimate is probably too high. Mr. Goodale, one of the party who ascended at that time, reported (as Mr. E. P. Baker writes me) that the lavas were thrown 60 or 80 feet above the brink of the crater on which the party were standing; and this confirms the report of the native guide and makes the height of the fountain nearly 900 feet.

1880, *July* 28.—At this date, Mr. W. T. Brigham found the crater without action as stated in his paper on page 35. The walls were much fissured about the southern pit; fresh-looking lavas covered the bottom; and a small area was seen on the west border of the pit, which was probably of recent ejection. Moreover, about the region around the crater there was much of the spongy scoria, some masses a foot in diameter.

1880, *Nov.* 5 to *Aug.* 10, 1881, nine months.—No "violent demonstrations or earthquake" announced the great eruption. The first light was visible in the evening of Friday from Waimea, and a few hours later in the night, from Hilo; and after midnight "the lavas could be distinctly seen leaping like a fountain into the air." The stream flowed northeastward, between those of 1852 and 1855, and by Sunday, the 7th, had reached the plain between Loa and Kea, a distance of 7 or 8 miles. From there it turned eastward toward Hilo.

A second stream, starting from near the source, flowed off to the southward toward Kilauea, which made in all a length of about ten miles.†

As observed by Judge Hitchcock‡ on the 10th or 11th, from the Kalaieha Hills at the south foot of Mt. Kea (see Plate I), the stream, along for 8 miles northward to the plain, was a continuous belt of fire, in steady flow, and also beyond this for some miles toward Hilo. The regular flow was interrupted half way from the plain to the source by the lavas rising into a huge dome, from which they flowed over like an immense fountain; but there was no fountain at the source.

In 4 months, on March 25, the stream was within 7 miles of

* Brigham, ibid., xxxvi, p. 33.

† Coan, Hitchcock, this Journal, III, xxi, 79, letter of Nov. 9–12, 1880; xxii, 227, 228, letter of June 28th and July 21st, 1881, and xxii, 322, letter of Aug. 24, 1881; Life in Hawaii, p. 325.

‡ This Journal, ibid., xxi, 79 and xxii, 226.

Hilo, or about 26 miles long; in $7\frac{2}{3}$ months, June 28, within 5 miles; in $8\frac{1}{2}$ months, July 18, about 2 miles; and August 10, 9 months after the outflow began, it stopped within three-fourths of a mile of Hilo. On June 30th, the movement, just beyond the Hilo tufa hills (the Halai Hills) was, as stated by Mr. D. H. Hitchcock, about 75 feet an hour.

In a communication to the Commercial Advertiser for November 20th,* the formation of the *aa* or clinker fields is described as follows by Judge Hitchcock. "The whole broad front of the then sluggish stream was a mass of solidified lava twelve to thirty feet in height, moving slowly along by breaking and bearing onward the crusted covering; along the whole line of its advance it was one crash of rolling, sliding, tumbling, red-hot rock, no liquid rock being in sight; there were no explosions, but a tremendous roaring, like ten thousand blast furnances all at work at once. The rough blocks lie piled together in the wildest confusion, many as large as ordinary houses. They [clinker-fields] form only when the movement is slow."

1882.—In this year (the month not stated) Capt. C. E. Dutton made his visit to the summit (Report, page 139). He found "no volcanic action whatever," "not even a wisp of steam issuing from any point;" and he makes no mention of any cinder cone at the bottom.

February, 1883.—Prof. C. H. Hitchcock was at the summit on the 15th, and found no activity. "A snow squall struck us, and *the entire floor of the crater was white with snow*."

1885.—In April, 1885, Rev. E. P. Baker visited the crater and descended to its bottom. It was all quiet. In September and October of 1885, Rev. J. M. Alexander made a survey of the summit crater, for the Government survey, as described on a following page. At the summit around the crater, for a breadth of a fourth of a mile he observed many blocks from 50 pounds to a ton in weight of a "solid, flinty lava." The bottom of the crater was mainly flat with fresh lavas, and had two cones in it as represented on the map, the southwestern 140 feet high and smoking; steam was rising from numerous cracks but no fires were visible.

1887, *January and February*.—In December, 1886, earthquakes began to be frequent in southwestern Hawaii, and in increasing numbers and violence; by the 12th of January they averaged three a day. Between 2^h 12′ A. M. of Jan. 17 and 4^h A. M. of the 18th, 314 shocks were counted in Kahuku by Mr. George Jones, 67 between the latter date and midnight, and 3 the following day. In Hilea, ten miles west, 618 were counted between 2 A. M. of the 16th and 7 P. M. of the 18th.

* Hitchcock, ibid., xxii, 228. Commercial Advertiser.

On the night of the 16th, with the sudden increase in the earthquakes, fires broke out at the summit near the small crater south of the summit crater (Pohaku o Hanalei, plate 1), and in a few hours disappeared. The height of the outbreak, according to Mr. E. P. Baker, was 11,500 feet. On the 18th, at 7 A. M., three hours after the cessation of the earthquakes, an outbreak took place in Kau, north of Kahuku. The lavas came from a fissure about 6,500 feet above the sea-level and 26 miles from the sea, and reached the sea at noon on the 19th, nearly four miles west of the flow of 1868. It extended the shore outward 300 to 500 feet without making a cinder cone on the sea-border. By noon of the 24th the flow had stopped, but the fires were still active along the stream.

At the outburst the lavas were thrown up into fountains; about 80 feet in diameter, and 80 to 100 in height. They were photographed; and two of the views, representing the same part of the stream and one fountain, are shown on plate III. Mr. Spencer, who visited the source on the 20th, states that there were fifteen fountains and that the highest was 200 feet; others make the height not over half this amount. The stream is stated to have flowed away bearing bowlders weighing tons, with explosions at intervals. The lava was mostly of the aa kind.

The earthquake in Kau threw down walls that had a northeast and southwest direction, the throw was to the southeast; and light wooden houses were moved 8 or 10 inches in the same direction or down the slope.

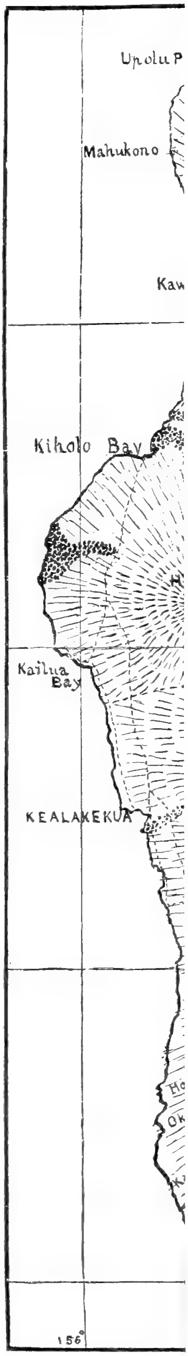
On February 20th, Mr. D. W. Hitchcock was at the summit and found vapors issuing from large fissures.

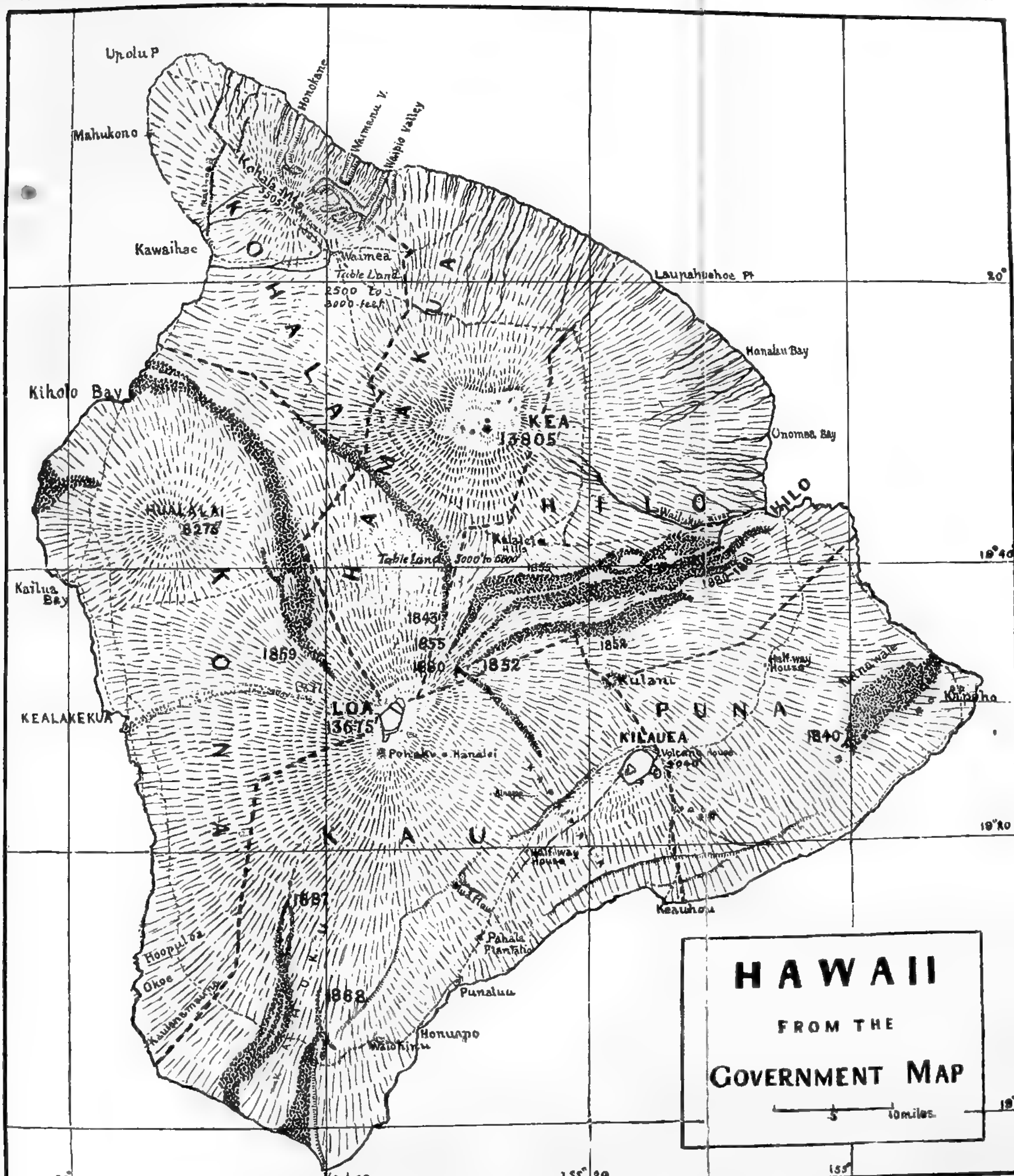
Kilauea was moderately active during the period of eruption, rather increasing in activity with its progress, but without evincing special disturbance or sympathy.*

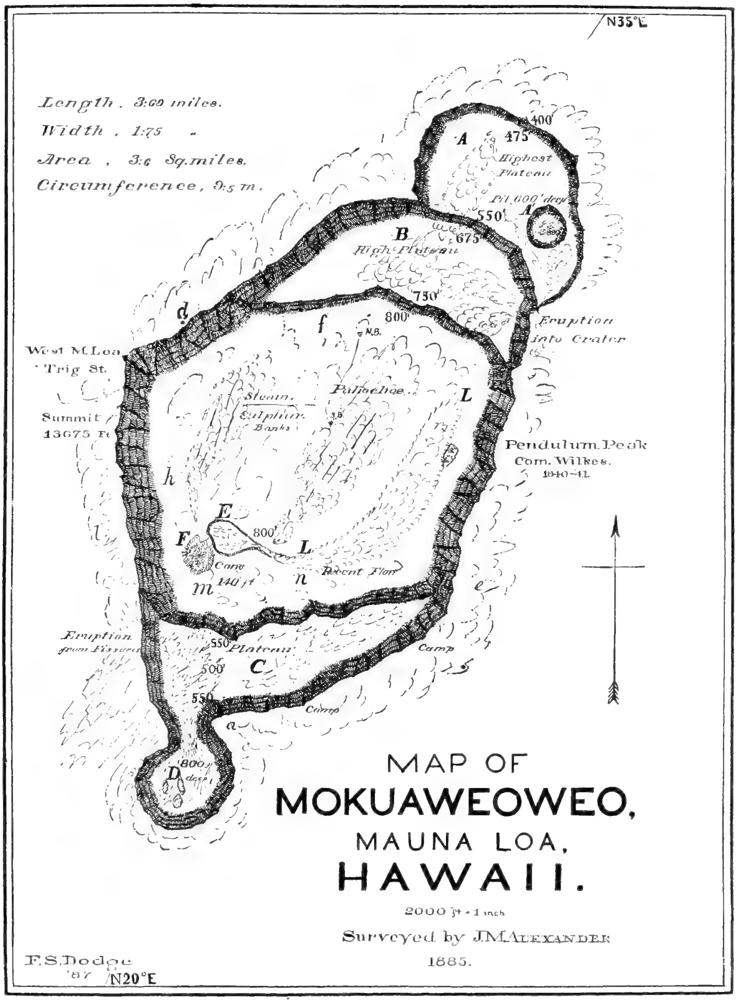
1887, *December* 29.—A letter from Mr. J. S. Emerson, dated Kohala, Hawaii, December 29th, states that the view of the summit of Loa from that place indicates activity in Mt. Loa. "Volumes of smoke and steam have been pouring out of the summit crater, but no glow or reflection of fire has been observed." "The summit is now heavily coated with snow." Another letter of April states that on March 29th, 1888, the signs of activity at the summit had disappeared; the exact time of their cessation was probably early in February."

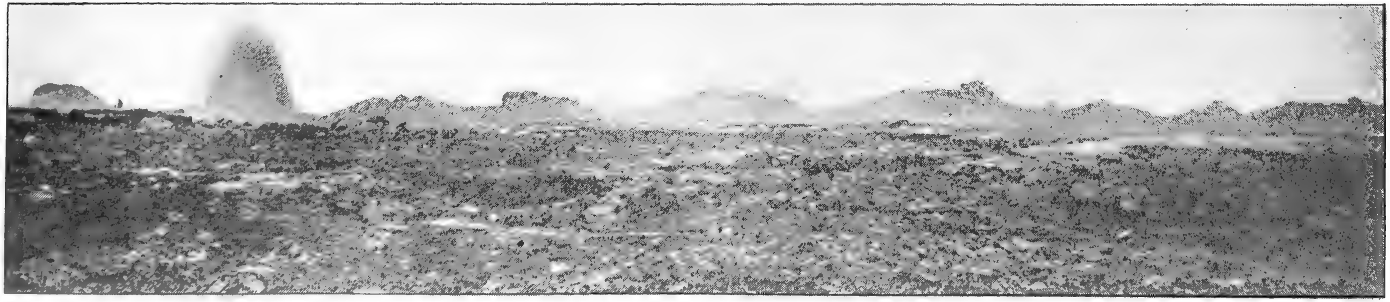
[To be continued.]

* The above is from the Pacific Commercial Advertiser and Hawaiian Gazette of Honolulu; this Journal, xxxiii, 310, 1887.


Upolu
Mahukono
Kiholo Bay
Kailua Bay
KEALAKEKUA
156°


HAWAII
FROM THE
GOVERNMENT MAP
5
10 miles
Upolu P.
Mahukono
Kawaihae
Kiholo Bay
Kailua Bay
KEALAKEKUA
Honokane
Waimanu V.
Waipio Valley
Kohala Mts.
Waimea
Table Land 2500 to 3000 feet
Laupahoehoe Pt.
Hanalau Bay
Onomea Bay
HILO
KEA
13805
HUALALAI
8275
Table Land 5000 to 6000
LOA
13675
KILAUEA
Volcano House
Kulani
Half-way House
Pohaku Hanalei
Kapoho
Pahala Plantation
Punaluu
Honuapo
Waiohinu
Ka Lae
Hoopuloa
Okoe
Kapaahu
Keauhou
1843
1855
1880
1852
1859
1887
1868
1840
1880-1881
20°
19°40
19°20
19°
156°
155°20
155°


N35°E
Length, 3:60 miles.
Width, 1:75 "
Area, 3:6 Sq. miles.
Circumference, 9:5 m.
A
475
400
Highest Plateau
Pit 600' deep
550'
A
B
675
High Plateau
730
800
Eruption into Crater
d
f
West M. Loa Trig St.
Steam
Sulphur Banks
Pohaehoe
L
Summit 13675 Ft.
Pendulum Peak Com. Wilkes. 1840-41.
h
E
800
F
L
Cone 140 ft
m
n
Recent Flow
e
Eruption from Fissures
550
Plateau
500
C
Camp
550
Camp
a
800 ft deep
D
MAP OF
MOKUAWEOWEO,
MAUNA LOA,
HAWAII.
2000 ft = 1 inch
Surveyed by J. M. Alexander
1885.
F. S. Dodge
'87
N20°E



TWO VIEWS OF A LAVA-FOUNTAIN AT THE ERUPTION OF JANUARY, 1887. From photographs.

Art. III.—*On the Summit Crater of Mt. Loa in* 1880 *and* 1885.

1. Notes on an Ascent in 1880, about three months before the great Eruption of that year; by W. T. Brigham.

On the first of May, 1880, fire was seen in the crater of Pohaku Hanalei on the summit of Mauna Loa. Persons who made the ascent saw a fire-fountain much like that observed in 1872, but no overflow followed, and the fires soon disappeared. On the morning of July 26, I left Kilauea for Kapapala. The next morning, while waiting at Stone's Ranch for a guide over the trackless beds of aa and clinker on the great mountain, an earthquake occurred at 8.30 a. m. local time. It lasted three seconds, and was accompanied by a loud subterranean noise resembling that of the looms in a cotton mill. The vibration was by no means so noticeable as the noise. Journeying over a grazing land covered with coarse grass and dotted here and there with blighted koa trees, we reached Ainapo (Land of Darkness) at 1.45 p. m. Although at an elevation of at least 5,000 feet, the temperature was at 75°. Late in the afternoon I mounted a fine mule that had been loaned me by a friend, and, with Ahuai for guide, left the ranch. In 1864, with Mr. Horace Mann, I climbed the mighty dome on foot on the opposite side; but this path was, if possible, worse. The forest had been burned, and the blackened stems of the trees were dismal objects unless covered with the *akalá*, a gigantic raspberry vine. The soil in these lower regions seems good, but the ground is much broken, and so full of holes that it would be very dangerous to ride out of the trail after dark. Even in the afternoon, vapors ascended from these holes, which often, if not always, communicated with caverns in the ancient lava streams, and as the day waned the vapors became more distinct. I found, as the average of several trials, that the temperature was only two or three degrees higher than the outside air. As we ascended, the actual temperature of the vapor in these holes increased, and of course the relative temperature was much higher. I inferred from this that the inner mountain mass was hotter than usual, as I had never observed so great a difference before, and that an eruption was at hand.

At the upper limit of vegetation we camped, giving our animals the little bundles of hay we had brought for the purpose. The night was cold and on the morning of July 28, at sunrise, the thermometer marked 52°. We broke camp at five o'clock and reached the summit at half-past ten. A rougher mass of

lava I have seldom seen and never before ridden over. Beds of aa were succeeded by piles of jagged scoria in fragments from one to twenty cubic feet in bulk, and over these my mule jumped like a chamois. At last we came upon a level plain from which had poured the lava that had hindered our ascent.

Although we were on the summit, the crater, Mokuaweoweo, did not at first appear, but on every side were rough piles of lava, some recent, and abundant deposits of the vesicular lava called *limu*. This limu is of a pale green color presenting the appearance of vegetation. Some fragments of it were a foot in diameter, the exterior glazed and of a much darker green, the whole very vesicular and so full of air as to float on water. In appearance it was frozen froth. In the midst of this waste plain we found the crater. Since I saw it fifteen years before great changes had occurred. Then no change but the gradual decay of time seemed imminent; all was the repose of the dead. There were some concentric cracks in the outer walls, but the lava between these cracks and the crater itself was so solid as to retain snow and ice all the summer, and the descent into the crater could be made only where the smaller craters broke into the outer wall. On both the east and west sides the precipices of gray, scarred and compact lava rose to the height of nearly a thousand feet, and seemed coeval with the mountain. At the present time, these ancient walls were cracked and tottering to their fall; in some places they much resembled a wall of loose stones artificially laid. It was dangerous to approach the brink of Pohaku Hanalei so loose were the lava blocks, and the vibrations caused by my approach seemed to extend downward several hundred feet toward the talus which had been the result of a tremor more severe than usual. By lying down I was able to look over and test the height by timing the fall of stones. The bottom of this lateral pit, as of the main crater, was comparatively level, without cones, and gave no indications of the source whence the fresh black lava that covered it had issued. At my former visit in 1864 there were two cones in Mokuaweoweo about 200 feet high near the eastern wall. In 1870, when Mr. Luther Severance ascended the mountain, there were no cones, although the bottom was much broken and sloped from west to east. From his sketch we learn that at *f** the wall was very steep; at *e* the height was estimated at 1,200 feet; at *h* were sulphur banks smoking, but not violently; *e* marks the point where the trail from Kapapala ends; *d* the point where Mr. Mann and I came to the crater in 1864; *b* is the small southern crater, Pohaku Hanalei, and *a* is where I found the wall tottering in 1880.

* For these letters, see Mr. Alexander's map, plate 2, to which they have been transferred. The crater called Pohaku Hanalei by Mr. Brigham is the South Crater of Mr. Alexander.—J. D. D.

In 1874 the crater was surveyed by Mr. John Lydgate, of the Government Survey, and the cones had again formed, two being in the northern lateral crater, and two (*m* and *n*) in the main pit. In 1880 with this survey before me, the changes seemed to be mostly in the outer walls which had crumbled extensively, changing the outline, but not enough to be indicated on a plan so small. In addition, the cross walls *f* and *k* were obliterated, and the bottom of the crater was covered with fresh lava. On this, along the edges was a talus of old lava from the walls, showing plainly that an earthquake had occurred since the eruption of May 1. No sulphur banks or steam jets were seen from either *e* or *a*, and the deposit of "limu," added to the roughness of the lava, deterred me from making the circuit of Pohaku Hanalei to examine a very extensive break on the farther side which looked fresh. Near this break was a black and glistening stream of lava, like that on the bottom of Mokuaweoweo, which extended from the edge of the opposite bank (*l*) as far to the westward as could be seen over the undulating surface. Whence this issued was not easily determined. If it was, as at first appeared to be the case, an overflow from the crater, how could this have been full and yet have left no fresh lava on the broken walls? Usually when a pit crater fills up and is emptied from beneath, the sinking lava leaves a rim or "Black Ledge;" but there is nothing of the sort here. If the stream flowed into the crater then the wall over which it came has tumbled down and so removed all traces. I finally concluded that it owed its origin to some of the inclined lava jets that spouted out clear of the crater.

My guide Ahuai had seen the fountain of May 1, and he assured me that it came up level with the outer walls of Pohaku Hanalei, so that the top was visible as he was lying down some distance from the brink. This would indicate a height of nearly a thousand feet—not an insignificant jet!

I was convinced that the eruption of May 1 was but the *avant courier* of a greater one, and as the termination of my visit was near, I asked those who were interested in these matters to watch for events and report to me. The new eruption began on the 5th of November, and it proved the beginning of the most extensive lava flow that has been recorded from the Hawaiian volcanoes.

2. On the Summit Crater in October, 1885, and its Survey; by J. M. Alexander. With Plate II.

During the year 1885 I was engaged for many months in surveying lands on Mauna Hualalai and Mauna Loa, in Hawaii, and in that way had an opportunity of making investigations

of craters and lava-flows that have some interest connected with the study of volcanic phenomena.

On the 1st of September, 1885, I set out in company with Mr. J. S. Emerson, of the Hawaiian Government Survey, to ascend the mountain from the table land east of Hualalai, along the south side of the lava-flow of 1859. Our route led first through a narrow belt of forest, consisting of mamane, ohia and sandalwood trees; then through a scanty vegetation of ohelos and the beautiful *Cyathodes Tameiameiæ*, and at last beyond the limits of vegetation, without a vestige of moss or lichen, over a waste of "pahoehoe" lava, traversed by tracts of "aa" and deep chasms.

At about two-thirds of the distance toward the summit we passed the ragged crater hill from which the outbreak of 1859 had issued, and here our path was strewed with pumice and "Pele's hair" from that eruption. An enormous quantity of lava was poured forth from the small fissure of this crater, forming a stream from half a mile to two miles wide, and reaching nearly thirty miles to the ocean at Kiholo. Lower down I counted eighteen species of ferns and a dozen kinds of phenogamous plants already growing on this flow.

Reaching the brink of the vast crater, we found that along it were numerous deep fissures filled with ice and water, making ready for avalanches into the crater. Here, and for a quarter of a mile below, we observed many rocks of different kind from the surface lavas, solid, flinty fragments of apparently the foundation walls, weighing from fifty pounds to a ton, which had formerly been hurled out during eruptions. I noticed similar rocks around the summit craters of Hualalai.

At evening the fog lifted and gave us a glimpse into the craters. The central crater (see Plate II) was surrounded by almost perpendicular walls, and had a pahoehoe floor streaked with gray sulphur cracks, from hundreds of which there issued columns of steam, and in the south end stood a still smoking cone. South of this central crater, there was a high plateau (C), and beyond this plateau, still farther south, an opening into another crater small and deep (D). In the opposite direction, north of the central crater, appeared another higher crater, like an upper plateau (B) from which a torrent of lava had once poured into the central crater, and north of this again another crater (A), like a still higher plateau, from which also lava had flowed southward.

Thus it was evident, as appeared more clearly by subsequent investigation, that Mokuaweoweo is not simply one crater, but a series of four or five craters, the walls of which have broken down, so that they have flowed into each other.

We erected a survey signal for determining the location and

height of the summit, and also of an important land boundary in the crater, viz: the corner where the four lands of Keauhou, Kahuku, Kapapala and Kaohe meet, which is at the cone in the central crater.

During the next month I ascended the mountain again, this time carrrying an excellent engineer's transit. In the clear frosty air at the summit station I was able to take the bearings of a dozen survey signals on the slopes and summit of Hualalai. The new spherical signal which I had erected was afterwards accurately determined by observations from more than twenty stations on Mauna Kea, Hualalai and in South Kona, and thus a trigonometrical station was at last located on the very summit of Mauna Loa.

On the second day I descended into the central crater, and found much of the bottom to consist of the most solid kind of "pahoehoe;" but in some large tracts the pahoehoe was covered with pumice, indicating the violence of the former surging and tossing of the lava. Just before reaching the cone we came to a deeper basin (E) twenty or more feet below the rest of the crater bottom and about 400 feet wide, covered with the most friable lava, swollen upward as though raised by air bubbles, and this basin extended into a lava flow (LL) north-eastward along the side of the crater. Probably this was the place of the last eruption and of most of the eruptions of this central crater. The cone, 140 feet high, was composed of pumice and friable lava still hot and smoking. We ascended it and set up a flag there for the boundary corner.

I returned to the second plateau to the north (B), and thence clambered out to the east of Mokuaweoweo by the route of a former cataract of lava from the summit into the crater, the black, shining spray of which lay spattered on the surrounding rocks. Farther south there were the courses of two other cataracts, which had poured directly into the central crater. At the summit I found the deep fissure from which these cataracts had been supplied with lava, and ascertained that it had also poured an immense stream north upon the first plateau and thence south into the central crater. Crossing from this place to the north over the first plateau I suddenly came to a circular crater in the bed of the plateau (A′), apparently 600 feet deep and 1,000 feet wide, with a cone in its center still smoking. The next day we took the transit to the stations in the crater, and the following surveyed along the western brink to the extreme south end, where we looked into the South Crater (D), which is about 800 feet deep and 2,500 feet wide. The length of the whole chasm I ascertained to be about 19,000 feet, the greatest breadth 9,000 feet, and the greatest depth 800 feet; and the area, three and six-tenths

square miles. The map* of Plate II is reduced from the map sent to the Government as the result of the survey.

On the southwest side, near the junction of the central crater with the south plateau (C), I found that there had been another eruption from fissures that were still smoking, and that this eruption had sent an immense stream southward toward Kahuku, and had also poured cataracts into the South Crater from all sides.

I had everywhere observed that there had been great flows from the summit brink down the mountain, and questioned whether the chasm had filled up and overflowed its brim. This, however, turned out to be an incorrect view. The flows have not been from the lowest parts of the brim, but from some of the highest, which could not have been the case in an overflow. The walls of the craters largely consist of loose, old weather-beaten rocks, and large tracts of the plateau are composed of old pahoehoe, that has not been overflowed for ages, which would not be the case if the craters had filled and overflowed.

These outbreaks from fissures around the rim indicate that the lava has rather poured *into* the crater than *out of it;* and that it has flowed from such fissures in vast streams down the mountain side. The question arises, How has the lava risen high enough to pour in extensive eruptions through these fissures, almost a thousand feet above the bottom of the crater, without rising in the crater and overflowing it? The same question has often been asked in respect to the rise of liquid lava to the summit of Mauna Loa without overflowing the open crater of Kilauea, 10,000 feet below.

While surveying the region, I was extremely interested in the arrangement of the craters; and now, having determined the situation of more than fifty of them on Mauna Loa, Hualalai and Mauna Kea, I have ascertained that there is a method in their arrangement. They are not arranged relatively to the mountain on which they are situated, but relatively to the points of the compass. There seems to have been a series of nearly parallel fissures through which these craters have risen, in lines running from S. 40 deg. E. to S. 60 deg. E. There are a few arranged in lines running N. 50 deg. E.

It has been remarked by Mr. W. T. Brigham, in his memoir of 1868 on the Volcanoes of the Hawaiian Islands, that while the general trend of the Hawaiian group and of the major axis of each island is N. 60 deg. W., there is no crater on the Islands whose major axis is parallel to this line. "On the contrary," he continues, "a very interesting parallelism is ob-

* To this map the depths of the different parts of Mokuaweoweo below the summit level have been added from estimates received in a letter from the author. The direction of the northern and southern halves of the longer diameter of the crater have also been added on the margin.—J. D. D.

served among all the craters, and invariably the longest diameter is north and south." It would be more correct to say that the major axes of the great craters are usually at right angles to the general axis of the group, i. e., about N. 30 deg. E. Haleakala and the ancient Kipahulu crater appear to take the other direction, but the statement is certainly true of the great craters of Kilauea and Mokuaweoweo, which have other points of resemblance.

Thus in both the highest walls are on the western side, and in both the action is working toward the southwest, as is indicated by the fact that the northeast craters are nearly filled up, while the deepest and active craters are in the southwest end of the depression.

Art. IV.—*On an Explanation of the action of a Magnet on Chemical Action;* by Henry A. Rowland and Louis Bell.*

In the year 1881 Prof. Remsen discovered that magnetism had a very remarkable action on the deposition of copper from one of its solutions on an iron plate, and he published an account in the *American Chemical Journal* for the year 1881. There were two distinct phenomena then described, the deposit of the copper in lines approximating to the equipotential lines of the magnet, and the protection of the iron from chemical action in lines around the edge of the poles. It seemed probable that the first effect was due to currents in the liquid produced by the action of the magnet on the electric currents set up in the liquid by the deposited copper in contact with the iron plate. The theory of the second kind of action was given by one of us, the action being ascribed to the actual attraction of the magnet for the iron and not to the magnetic state of the latter. It is well known since the time of Faraday that a particle of magnetic material in a magnetic field tends to pass from the weaker to the stronger portions of the field, and this is expressed mathematically by stating that the force acting on the particle in any direction is proportional to the rate of variation of the square of the magnetic force in that direction. This rate of variation is greatest near the edges and points of a magnetic pole, and more work will be required to tear away a particle of iron or steel from such an edge or point than from a hollow. This follows whether the tearing away is done mechanically or chemically. Hence the points and edges of a magnetic pole, either of a permanent or induced magnet, are protected from chemical action.

* Read at the Manchester meeting of the British Association, September, 1887.

One of Prof. Remsen's experiments illustrates this most beautifully. He places pieces of iron wire in a strong magnetic field, with their axes along the lines of force On attacking them with dilute nitric acid they are eaten away until they assume an hour-glass form, and are furthermore pitted on the ends in a remarkable manner. On Prof. Remsen's signifying that he had abandoned the field for the present, we set to work to illustrate the matter in another manner by means of the electric currents produced from the change in the electrochemical nature of the points and hollows of the iron.

The first experiments were conducted as follows: Two bits of iron or steel wire about 1^{mm} in diameter and 10^{mm} long were imbedded side by side in insulating material, and each was attached to an insulated wire. One of them was filed to a sharp point, which was exposed by cutting away a little of the insulation, while the other was laid bare on a portion of the side. The connecting wires were led to a reflecting galvanometer, and the whole arrangement was placed in a small beaker held closely between the poles of a large electromagnet, the iron wires being in the direction of the lines of force. When there was acid or any other substance acting upon iron in the beaker, there was always a deflection of the galvanometer due to the slightly different action on the two poles. When the magnet was excited the phenomena were various. When dilute nitric acid was placed in the beaker and the magnet excited, there was always a strong throw of the needle at the moment of making circuit, in the same direction as if the sharp pointed pole had been replaced by copper and the other by zinc. This throw did not usually result in a permanent deflection, but the needle slowly returned toward its starting point and nearly always passed it and produced a reversed deflection. This latter effect was disregarded for the time being, and attention was directed to the laws that governed the apparent "protective throw," since the reversal was so long delayed as to be quite evidently due to after effects and not to the immediate action of the magnet.

With nitric acid this throw was always present in greater or less degree, and sometimes remained for some minutes as a temporary deflection, the time varying from this down to a few seconds. The throw was independent of direction of current through the magnet, and apparently varied in amount with the strength of acid and with the amount of deflection due to the original difference between the poles. This latter fact simply means that the effect produced by the magnet is more noticeable as the action on the iron becomes freer.

When a pair of little plates exposed in the middle were substituted for the wires, or when the exposed point of the latter was filed to a flat surface, the protective throw disappeared, though

it is to be noted that the deflection often gradually reversed in direction when the current was sent through the magnet; i. e., only the latter part of the previous phenomenon appeared under these circumstances.

When the poles, instead of being placed in the field along the lines of force, were held firmly perpendicular to them, the protective throw disappeared completely, though as before there was a slight reverse after-effect.

Some of Professor Remsen's experiments on the corrosion of a wire in strong nitric acid were repeated with the same results as he obtained, viz: the wire was eaten away to the general dumb-bell form, though the protected ends instead of being club-shaped were perceptibly hollowed. When the wire thus exposed was filed to a sharp point the extreme point was very perfectly protected, while there was a slight tendency to hollow the sides of the cone, and the remainder of the wire was as in the previous experiments. In both cases the bars were steel and showed near the ends curious corrugations, the metal being left here and there in sharp ridges and points. In one case the cylinder was eaten away on sides and ends so that a ridge of almost knife-like sharpness was left projecting from the periphery of the ends.

These were the principal phenomena observed with nitric acid. Since this acid is the only one which attacks iron freely in the cold, in Prof. Remsen's experiment, this was the one to which experiments were in the main confined. With the present method, however, it was possible to trace the effect of the magnet whenever there was the slightest action on the iron, and consequently a large number of substances, some of which hardly produce any action, could be used with not a little facility.

In thus extending the experiments some difficulties had to be encountered. In many cases the action on the iron was so irregular that it was only after numerous experiments under widely varying conditions that the effect of the magnet could be definitely determined. Frequently the direction of the original action would be reversed in the course of a series of experiments without any apparent cause, but in such case the direction of the effect due to the magnet remained always unchanged, uniformly showing protection of the point so long as the wires remained parallel to the lines of force. When, however, the original action and the magnetic effect coincided in direction, the repetition of the latter showed a decided tendency to increase the former.

When using solutions of various salts more or less freely precipitated by the iron, it frequently happened that the normal protective throw was nearly or quite absent, but showed itself when the magnet circuit was broken as a violent throw in the reverse direction, showing that the combination had been act-

ing like a miniature storage battery which promptly discharged itself when the charging was discontinued by breaking the current through the magnet. The gradual reversal of the current some little time after exciting the magnet was noted frequently in these cases, as before. Owing to this peculiarity and their generally very irregular action, the various salts were disagreeable substances to experiment with, though as a rule they gave positive results.

Unless the poles were kept clean experimenting became difficult from the accumulation of decomposition products about them and oxidation of their surfaces. A few experiments showed how easily the original deflection could be modified, nearly annulled or even reversed in direction by slight differences in the condition of the poles. These difficulties of the method are, however, more than counterbalanced by its rapidity and delicacy when proper precautions are taken.

Nearly thirty substances were tested in the manner previously described; but comparatively few of them gave very decided effects with the magnet, though, as later experiments have shown, the protective action is a general one. The substances first tried were as follows. The table shows the various acids and salts tried, and their effects as shown by the original apparatus:

Substances.	Effect due to magnet.	Notes.
Nitric acid	Strong.	Always powerful protective throw.
Sulphuric "	Little or none.	Does not act very readily on the iron.
Hydrochloric acid	" "	
Acetic "	None.	
Formic "	"	
Oxalic "	"	
Tartaric "	"	
Chromic "	Some effect.	Sometimes quite distinct throw, irregular.
Perchloric "	"	Much less marked than with chromic.
Chloric "	None.	
Bromic "	"	
Phosphoric "	"	Hardly any effect on iron.
Permanganic "	Slight effect.	More than with perchloric.
Chlorine water	Decided "	
Bromine "	"	
Iodine "	"	
Copper sulphate	"	Mainly showing as throw, on breaking.
" nitrate	Some.	" " "
" acetate	"	" " "
" chloride	"	" " "
" tartrate	Slight.	
Mercuric bromide	Some.	Throw, on breaking.
" chloride	"	Very slight solution, weak.
Mercurous nitrate	"	Mainly as throw on breaking.
Ferric chloride	Decided.	Both protective throw, and sometimes on breaking.
Silver nitrate	Some.	Action very irregular.
Platinum tetrachloride	"	" "

Several things are worthy of note in this list. In the first place those solutions of metallic salts which are precipitated by iron all show distinct signs of protective action when the current is passed through the magnet. Of the various acids this is not generally true; only those show the magnetic effect, which act on iron without the evolution of hydrogen, and are powerful oxidizing agents. In general, substances which acted without the evolution of hydrogen gave an effect with the magnet.

From these experiments it was quite evident that the protective action, whatever its cause, was more general than at first appeared and steps were next taken to extend it to the other magnetic metals. Small bars were made of nickel and cobalt and tried in the same manner as before. These metals are acted on but very slightly by most acids, and the range of substances which could be used was therefore very small, but all the substances which gave the magnetic effect with iron poles gave a precisely similar, though much smaller effect, whenever they were capable of acting at all on the nickel and cobalt. This was notably the case with nitric acid, bromine water, chlorine water, and platinum tetrachloride, which were the substances acting most readily on the metals in question. Even with these powerful agents, however, the magnetic action was very much less than with iron, and experimentation on metals even more weakly magnetic was evidently hopeless.

As a preliminary step toward ascertaining the cause of the magnetic action and its nonappearance where the active substance evolved hydrogen, it now became necessary to discover and if possible eliminate the cause of the reversal of the current which regularly followed the protective throw. Experiments soon showed that it could not be ascribed to accumulation of decomposition products around the electrodes, and polarization, while it could readily neutralize the original deflection, could not reverse its direction. Whatever the cause, it was one which did not act with any great regularity, and it was soon found that stirring the liquid while the magnet was on, uniformly produced the effect observed. Since one pole was simply exposed over a small portion of its side while the other had a sharp projecting point, it was the latter which was most freely attacked when there were currents in the liquid, whether these were stirred up artificially or were produced by the change in galvanic action due to the presence of the magnet. When the poles were placed in fine sand saturated with acid this reversing action was much diminished, and in fact anything which tended to hinder free circulation of the liquid produced the same effect. Several materials were tried and of these the most successful was an acidulated gelatine

which was allowed to harden around the poles. In this case the protective throw was not nearly as large as in the free acid, since the electrodes tended to become polarized while the gelatine was hardening, and only weakly acid gelatine would harden at all; but the reversing action completely disappeared, so that, when the magnet was put on, a permanent deflection was produced instead of a transitory throw.

This point being cleared up attention was next turned to the negative results obtained with acids which attack iron with evolution of hydrogen. The galvanometer was made much more sensitive and removed from any possible disturbing action due to the magnet; and with these precautions the original experiments were repeated, it seeming probable that even if the magnetic effect were virtually annulled by the hydrogen evolved, some residual effect might be observed.

This residual effect was soon detected, first with hydrobromic acid, and then with hydrochloric, hydriodic, sulphuric and others. The strongest observed effect was with hydriodic acid, but as this may possibly have contained traces of free iodine it may be regarded as somewhat doubtful. The effect in all these cases was very small, and though now and then suspected in the previous work, could not have been definitely determined, much less measured.

Some rough measurements were made on the electromotive forces involved in this class of phenomena by getting the throw of the galvanometer for various small known values of the E. M. F. The values found varied greatly, ranging from less than 0·0001 volt in case of the acids evolving hydrogen, up to 0·02 or 0·03 volts with nitric acid and certain salts. These were the changes produced by the magnet, while the initial electromotive forces normally existing between the poles would be, roughly speaking, from 0·001 to nearly 0·05 volts, never disappearing and rarely reaching the latter figure.

From these experiments it therefore appears that the protective action of the magnetic field is general, extending to all substances which act chemically on the magnetic metals. While this is so, the strongest effect is obtained with those substances which act without the evolution of hydrogen. But the series is really quite continuous, perchloric acid for instance producing but little more effect than hydrobromic, while this in turn differs less from perchloric than from an acid like acetic. It seems probable that the action of the hydrogen evolved is partially to shield the pole at which it is evolved, and lessen the difference between the poles produced by the magnet. It probably acts merely mechanically, for it is to be noted that those acids which evolve a gas other than hydrogen (perchloric acid, for instance), which is not absorbed by the

water, tend to produce little magnetic effect compared with those which act without the evolution of any gas.

As to the actual cause of the protective action exercised by the magnetic field, all these experiments go to show that it is quite independent of the substance acting, with the exception above noted, and is probably due to the attractive action of the magnet on the magnetic metals forming the poles subjected to chemical action, as we have before explained.

In the first place, whenever iron is acted upon chemically in a magnetic field those portions of it about which the magnetic force varies most rapidly are very noticeably protected, and this protection as nearly as can be judged varies very nearly with the above quantity. Wherever there is a point there is almost complete protection, and wherever there is a flat surface, no matter in how strong a field, it is attacked freely. Whenever in the course of the action there is a point formed, the above condition is satisfied and protection at once appears. Thus, in the steel bars experimented on, whenever the acid reached a spot slightly harder than the surrounding portions it produced a little elevation from which the lines of force diverged, and still further shielding it produced a ridge or point, sharp as if cut with a minute chisel. Nickel and cobalt tend to act like iron, though they are attacked with such difficulty that the phenomena are much less strongly marked. With the non-magnetic metals they are completely absent. Now, turning to the experiments with the wires connected with a galvanometer, the same facts appear in a slightly different form.

When the poles were placed perpendicular to the lines of force instead of parallel to them, the magnet produced no effect whatever, showing, first, that the effect previously observed depended not merely on the existence of magnetic force but on its relation to the poles, and, secondly, that when the poles were so placed as to produce little deflection of the lines of force the protective effect disappeared.

When the pointed pole was blunted the effect practically disappeared, the poles remaining parallel to the lines of force, and when plates were substituted for the wires no effect was produced in any position, showing that the phenomena were not due to the directions of magnetization but to the nature of the field at the exposed points. In short, whatever the shape or arrangement of the exposed surfaces, if at any point or points the rate of variation of the square of the magnetic force is greater than elsewhere, such points will be protected, while if the force is sensibly constant over the surfaces exposed there will be no protection at any point. With all the forms of experimentation tried this law held without exception. It therefore appears that the particles of magnetic mate-

rial on which the chemical action could take place are governed by the general law of magnetic attraction and are held in place against chemical energy precisely as they would be held against purely mechanical force. To sum up:

When the magnetic metals are exposed to chemical action in a magnetic field such action is decreased or arrested at any points where the rate of variation of the square of the magnetic force tends toward a maximum.

It is quite clear that the above law expresses the facts thus far obtained, and while in any given case the action of the magnet is often complicated by subsidiary effects due to currents or by-products, the mechanical laws of motion of particles in a magnetic field hold here as elsewhere and cause the chemical action to be confined to those points where the magnetic force is comparatively uniform.

The effect of currents set up in the liquid during the action of the magnet cannot be disregarded especially in such experiments as those of Nichols (this Journal, xxxi, 272, 1886) where the material acted on was powdered iron and the disturbances produced by the magnet would be particularly potent. The recent experiments of Colardeau (Journal de Physique, March, 1887) while perhaps neglecting the question of direct protection of the poles, have furnished additional proof of the purely mechanical action of the magnet by reproducing some of the characteristic phenomena where chemical action was eliminated and the only forces acting were the ordinary magnetic attractions.

An attempt was made to reverse the magnetic action, i. e. to deposit iron in a magnetic field and increase its deposition where there was a sharp pole immediately behind the plate on which the iron was being deposited. This attempt failed. The action was very irregular and the results not decisive. The question of stirring effect was also examined. Usually stirring the liquid about one pole increased the action on that pole, but sometimes produced little effect or even decreased it. This however is in entire agreement with the irregular action sometimes observed in the case of the after-effect in the original experiments.

An excellent method of experiment is to imbed an iron point in wax leaving the minute point exposed: imbed a flat plate also in wax and expose a point in its center. Place the point opposite to the plate, but not too near and place in the liquid between the poles of a magnet and attach to the galvanometer as before.

There is a wide field for experiment in the direction indicated above, for it is certainly very curious that the effect varies so much. If hydrogen were as magnetic as iron, of

course acids which liberated it would have no action. But it is useless to theorize blindly without further experiment; and we are drawn off by other fields of research.

In this Journal for 1886, (l. c.) Professor E. L. Nichols has investigated the action of acids on iron in a magnetic field. He remarks that the dissolving of iron in a magnetic field is the same as removing it to an infinite distance and hence the amount of heat generated by the reaction should differ when this takes place within or without the magnetic field. Had he calculated this amount of heat due to the work of withdrawing it from the field, he would probably have found his method of experiment entirely too rough to show the difference, for it must be very small. He has not given the data, however, for us to make the calculation. The results of the experiments were inconclusive as to whether there was greater or less heat generated in the field than without.

In the same Journal for December, 1887, he describes experiments on the action of the magnet on the passive state of iron in the magnetic field. In a note to this paper and in another paper in this Journal for April, 1888, he describes an experiment similar to the one in this paper but without our theory with regard to the action of points. Indeed he states that the ends of his bars acted like zinc, while the middle was like platinum, *a conclusion directly opposite to ours.* The reason of this difference has been shown in this paper to be probably due to the currents set up in the liquid by the reaction of the magnet and the electric currents in the liquid.

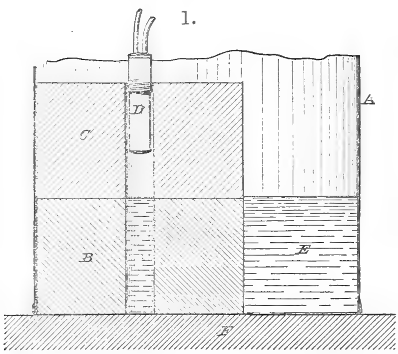
In conclusion we may remark that our results differ from Professor Nichols in this: First, we have given the exact mathematical theory of the action and have confirmed it by our experiments, having studied and avoided many sources of error, while Professor Nichols gives no theory and does not notice the action of points. Secondly, our experiments give a protective action to the points and ends of bars, while Professor Nichols thinks the reverse holds and that these are more easily dissolved than unmagnetized iron.

ART. V.—*Wave-like effects produced by the Detonation of Gun-cotton;* by CHARLES E. MUNROE. With Plate IV.

HAVING had occasion recently to determine how readily gun-cotton which was completely saturated with water could be detonated, I employed for the purpose a tin can, with a smooth flat bottom to hold the gun-cotton disk and then filled the can with sufficient water to just completely cover the disk. A paraffined dry disk of gun-cotton, to serve as a primer, was then laid directly on top of and in contact with the wet disk, and a detonator containing thirty-five grains of mercury fulminate was inserted in the primer for the purpose of firing it.

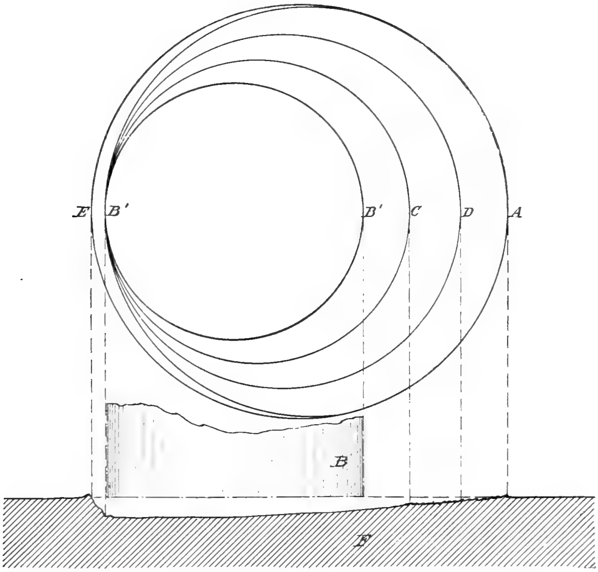
The arrangement is shown in fig. 1, where *A* represents the can, *B* the disk of wet gun-cotton, *C* the disk of dry gun-cotton, *D* the detonator, *E* the water and *F* the iron beam on which it rested. The gun-cotton disks had a diameter of $3\frac{1}{2}$ inches each, while the can had a diameter of $5\frac{1}{2}$ inches and, as the gun-cotton disks were placed with their cylindrical axes parallel to that of the can and with one face in contact with the side of the can, there was a crescent-shaped space about the gun-cotton at the bottom of the can, two inches wide at its greatest width, which was covered by water only.

1.

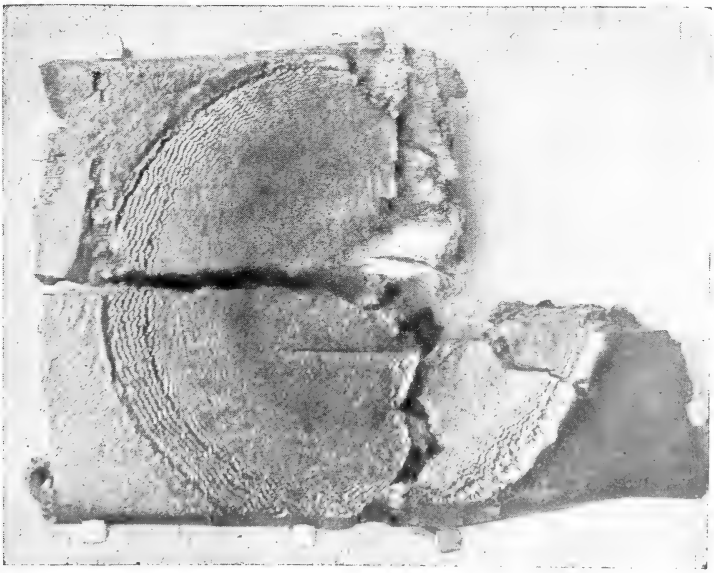


The can, with its contents arranged as described, was placed on the smooth face of a heavy wrought iron beam and detonated. The effect produced on the iron is shown in fig. 2 (Plate IV), which is reproduced from a photograph of such pieces of the fractured beam as were recovered. Inspection of the impressed surface shows a comparatively smooth and deep indentation immediately under the place occupied by the gun-cotton, which has an area nearly equal to that of the base of the gun-cotton disk. Surrounding this is a crescent-shaped space, about five-eighths of an inch wide at its greatest width, which appears slightly undulating when examined by a low-powered lens, and then follows a series of breakers, concentrically arranged about the impression of the base of the gun-cotton disk, which are plainly visible to the naked eye. These breakers appear to consist of lines of waves which are undulating in paths nearly normal to the direction of propagation of the breakers, while

3.



2.



the breakers or lines of waves appear to be divided pretty sharply into two groups of different amplitudes, the exterior group having the greatest amplitude. In all cases the crests of the waves are turned from the center, so that if the hand is passed from the center outward over the plate it glides freely, but if passed in the opposite direction it is caught by the sharp projecting points. This feature can easily be seen with a pocket lens.

The impression produced is shown in section in fig. 3 where *AE* represents the extreme area having a diameter slightly greater than that of the can. *B* the position of the wet gun-cotton disk before detonation. *B′B′* the impression produced by the base of the disks. *B′C* the space where the waves are not visible to the naked eye. *CD* and *DA* the spaces occupied by the two groups of breakers visible to the naked eye. *B′E* represents the eroded and fused metal which marks the most deeply indented part of the plate. The cross-section of the beam *F* shows very clearly that the area of marked depression extends much beyond the limit of area of the gun-cotton, and quite to, if not beyond, the extreme area of the base of the can. The experiment, as described above, has been repeated several times and always with the same result.

Dr. John Trowbridge has very kindly measured for me the intervals between the breakers in the outer group, these measurements being taken from crest to crest at six different points. As, owing to the nature of the object, nothing remained sharply in focus under the microscope of the comparator, the results are only approximate. The data are as follows, the lengths being given in millimeters :

No.	R.	D.	R.	D.	R.	D.	R.	D.	R.	D.	R.	D.
1	0	3·6	0	3·	0	3·1	0	3·	0	2·6	0	2·8
2	3·6	2·1	3·	1·7	3·1	1·7	3·	1·3	2·6	1·4	2·8	1·1
3	5·7	2·	4·7	1·8	4·8	1.8	4·3	1·4	4·	1·5	3·9	1·8
4	7·7	1·3	6·5	1·5	6·6	1·7	5·7	1·8	5·5	1·5	5·7	1·3
5	9·	2·	8·	1·5	8·3	1·7	7·5	1·6	7·	1·8	7·	1·5
6	11·	1·5	9·5	2·	10·	1·3	9·1	1·7	8·8	1·5	8·5	1·5
7	12·5		11·5		11·3		10·8		10·3		10·	1·9
8											11·9	6·
9											12·5	

These measurements were taken from the exterior toward the center of explosion, and it will be noticed that the first interval is about twice as great as any of the others in a set. Examination of the photo-engraving shows that at this point the propagation of the undulations must have been affected by the retaining walls of the containing vessel. Omitting this inter-

val we find the average of each of the six sets of differences to be respectively 1·78, 1·70, 1·64, 1·56, 1·54, 1·39, and the average of all the differences to be 1·59.

Several hypotheses have occurred to me in explanation of this phenomenon, but as I have not as yet been able to put them to the test of experiment I am not prepared to submit any of them, though I intend to test them as opportunity offers. As, however, the objects for which this station is created does not embrace the carrying on of researches for purely theoretical purposes, it may be some time before the desired opportunity for experiments occurs, and hence I desire to place on record this preliminary observation. I ought to add however that the idea has suggested itself to me that we may possibly find in this phenomenon a means for distinguishing between and perhaps measuring the effects of different detonating explosives.

I am deeply indebted to Commander C. F. Goodrich, U. S. N., Inspector in charge of the Torpedo Station, for permission to publish this account, and to Mr. Arendt Ångstrom, C. E., for the precise drawings used in figs. 1 and 3.

Torpedo Station, Newport, R. I.

ART. VI.—*Mode of Reading Mirror Galvanometers, etc.*; by R. W. WILLSON, Ph.D.

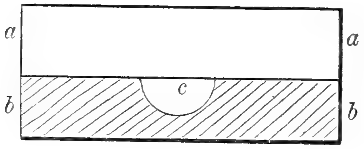
IN physical work which requires the observation of small angles of deflection, such as the reading of a reflecting galvanometer, it is sometimes found that the use of telescope and scale is inconvenient or trying to the eye, while the method with lamp and scale has other disadvantages beside that of requiring a darkened room.

In many such cases a method of reading may be used, which I do not remember to have seen described, but which I have found so useful that I think it merits description. Though often more convenient than the telescope and scale it does not compare with the latter in accuracy; but in this respect it is not much inferior to the spot of light, while it is free from some of the most objectionable features of that method.

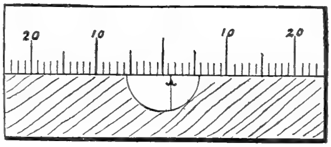
Replacing the telescope by a peep hole gives for many purposes a very convenient means of reading, where the magnifying power of the telescope can be dispensed with, a vertical line being drawn on the surface of the mirror to fix the sight line. A better plan, however, consists in placing in front of the movable mirror, and as near it as possible, a good-sized piece of thin plate mirror, from half of which the silvering has been removed, so that the silvered and unsilvered portions meet in a

horizontal line which crosses the center of the movable mirror; usually the reflecting portion is placed above, as shown in fig. 1, where *a* and *b* represent the silvered and unsilvered portions of the fixed mirror and *c* the movable mirror.

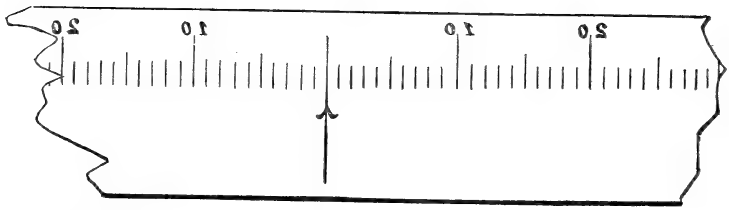
1



3



2



The instrument is so adjusted that the movable mirror when in its position of rest is nearly parallel to the fixed mirror. The scale used, as shown in fig. 2, has its middle division line prolonged downward to form an index; this scale being brought in front of the mirror, the eye is placed at the proper height to see, as in fig. 3, the image of the scale in the upper fixed mirror, the lower ends of the divisions coincident with the lower edge of the silvering, while the index is seen nearly continuous with the middle line of the scale, but reflected from the movable mirror; any deflection of the latter causes the image of the index to move along the lower edge of the reflected scale by an amount corresponding to the double angle of deflection.*

It is obvious that this construction does not interfere with the use of the instrument with lamp, or telescope and scale, the lower portion of the fixed mirror acting as the usual covering glass; it is then desirable, however, to give the latter a slight forward inclination to avoid double reflection; a sufficient inclination may be given with the leveling screws, without interfering with the mode of reading, above described, unless the lines of the graduation are very short.

* A simple geometrical consideration shows that if the scale reading be n, the angle of deflection α, the distance of the scale from the fixed mirror A, and the distance between the two mirrors d, $\tan 2\alpha = \frac{n}{A-d}$; A and d, if necessary, corrected for the thickness of the glass in the usual way.

The advantage of the method arises mainly from the natural and easy use of the eye; to secure this it is desirable that the scale should be sufficiently open to be read without straining the eye.

The fixed mirror should be as large as possible, especially in the horizontal direction, to facilitate the bringing of the eye into the proper position without effort.

It is also important if the movable mirror is round that the line of division between the silvered and unsilvered surfaces shall cross it nearly in a diameter in order that the position of the eye may not be too much restricted, as is the case if the line is very short in which the fixed and movable mirrors overlap. Where it is practicable a rectangular mirror is to be preferred.

Jefferson Physical Laboratory, April, 1888.

Art. VII.—*Bertrandite from Mt. Antero, Colorado*; by Samuel L. Penfield.

This rare mineral was first identified as a new species by M. E. Bertrand* from the study of a few small crystals collected from a pegmatite vein at Petit Port, near Nantes, France. M. Des Cloizeaux† has also identified the mineral at the gneiss quarries at Barbin, near Nantes, while M. A. Damour‡ has analyzed it and determined its composition to be $H_2Be_2Si_2O_9$; he also gave to it the name Bertrandite. The mineral has since been identified by R. Scharizer§ at a feldspar quarry near Pisek, Bohemia, where it occurs lining cavities left by the decomposition and disappearance of beryl crystals. At all of these localities the crystals are minute and are found only in small quantities. The crystalline form determined by Bertrand and Des Cloizeaux is orthorhombic, while Scharizer finds grounds for believing that the crystals are monoclinic with close approximation in form and optical properties to orthorhombic symmetry.

The single hand-specimen in the author's possession was selected by Mr. W. B. Smith, of Denver, Col., from a lot of material collected during the past summer at Mt. Antero in the search for specimens of phenacite. The crystals of bertrandite are attached to quartz which is associated with beryl.

* Bull. Soc. Min. de France, iii, 1880, p. 96.
† Bull. Soc. Min. de France, v, 1882, p. 176.
‡ Bull. Soc. Min. de France, vi, 1883, p. 252.
§ Zeitschr. Kryst., xiv, 1888, p. 33.

Other minerals occurring at the locality are phenacite, orthoclase, muscovite and fluorite.

The crystals are little rectangular blades 5^{mm} long, 2^{mm} wide and $0{\cdot}2$–$0{\cdot}4^{mm}$ thick. The largest faces, 5×2^{mm}, correspond to the basal plane of Bertrand lengthened out in the direction of the brachy-axis, $\breve{a}$, and marked by slight striations parallel to the shorter diameter or macro-axis, $\bar{b}$. Opposite this flat basal plane the crystals have a curved surface composed of the basal plane and brachydomes in oscillatory combination. The curved surface either joins the basal plane directly, forming a sharp, thin edge along the whole length of the crystal, or a narrow brachypinacoid is present between them. This curious development gives to the crystals a hemimorphic aspect which is very characteristic and not accidental; for all of the eight or ten crystals on the specimen were of this same character. The general shape of the crystals is that of a thin slice cut from the side of a cylinder parallel to its axis. The crystals are attached at one end and are terminated at the free end by a macropinacoid. The observed planes are therefore the three pinacoids, one of the basal planes being rounded by oscillatory combinations parallel to the brachy-axis. The faces have a good luster, that of the basal plane being pearly, the others vitreous. They are not well suited for measurement. There was one V-shaped twin in the specimen, the twinning plane being the brachy-dome 031 (3-$\breve{i}$) of Bertrand. The flat basal planes formed the outside limbs of the V and made an angle of 61° 52′ with one another, the curved surfaces formed the re-entrant angle. Similar twins are described by Bertrand with re-entrant angle of about 60°. Two cleavages were identified, prismatic and basal, both highly perfect. The measured angles are as follows:

		Calculated:	Bertrand.
$c \wedge b$	$001 \wedge 010$ approx.,	89° 54′	90°
$m \wedge m$	$110 \wedge 1\bar{1}0$ both cleavage,	59° 34′	58° 40′
$m \wedge m$	$110 \wedge \bar{1}10$ " "	120° 36′	121° 20′
$a \wedge m$	$100 \wedge \bar{1}10$ m cleavage,	150° 50′	149° 40′
$c \wedge \underline{c}$	$001 \wedge \underline{001}$ twin,	118° 8′	120° 50′

These values differ quite widely from the calculated values of Bertrand, but if we regard the cleavage angle $m \wedge m =$ 59° 34′ as good (it was certainly free from disturbing influences such as striations) and couple with it the angle of the twin $c \wedge \underline{c} = 118° 8′$, we obtain the axial ratio for orthorhombic axes

$$c : b : a = 0{\cdot}5953 : 1\cdot : 0{\cdot}5723.$$

The important measurements of Des Cloizeaux and Scharizer, with the values calculated from the above axes, are:

		Des Cloizeaux.	Scharizer.	Calculated.
$b \wedge m$,	$010 \wedge 110$		$\bar{1}00 \wedge \bar{1}10$, 61° 13′ 10″	60° 13′
"	"		$\bar{1}00 \wedge \bar{1}\bar{1}0$, 60° 12′ 40″	"
$a \wedge z$,	$100 \wedge 130$	59° 57′		59° 47′
$b \wedge z$,	$010 \wedge 130$	30° 17½′		30° 13′
$z \wedge z$,	$130 \wedge 130$	129° 30′ (twin)		129° 34′
$a \wedge \bar{a}$.	$100 \wedge \overline{100}$	60° 40′ (twin)		60° 24′
$c \wedge \bar{e}'$,	$001 \wedge \overline{031}$		$001 \wedge \bar{3}0\bar{1}$, 119° 15′ 10″	119° 15′
$b \wedge e'$,	$010 \wedge 03\bar{1}$		$\bar{1}00 \wedge \bar{3}0\bar{1}$, 28° 44′ 20″	29° 15′
$m \wedge e$,	$110 \wedge 031$		$\bar{1}10 \wedge \bar{3}0\bar{1}$, 64° 34′ 20″	64° 19′
$m \wedge e$,			$\bar{1}\bar{1}0 \wedge \bar{3}0\bar{1}$, 64° 27′ 40″	" "
$m \wedge \eta$,	$110 \wedge 021$		$\bar{1}10 \wedge \bar{2}0\bar{1}$, 67° 38′ 30″	67° 39′
"			$\bar{1}\bar{1}0 \wedge \bar{2}0\bar{1}$, 67° 37′ 30″	" "
$e \wedge \eta$,	$031 \wedge 021$		$\bar{3}0\bar{1} \wedge \bar{2}0\bar{1}$, 10° 19′	10° 47′

The above measured angles agree very well with the calculated values, and where the difference is large the reason may be found in the uncertainty of the measurements made on so small crystals. Scharizer's measurements agree about as well with these orthorhombic values as with his own calculated values for monoclinic axes.

I cannot give a reason for the hemimorphic development of the basal plane. If Scharizer is correct in assuming that the crystals are monoclinic with the brachy-axis of Bertrand as the ortho-axis, such a development might result from twinning about an orthopinacoid, one basal plane being converted into a curved surface by oscillations with hemi-orthodomes, symmetrically situated on either side of the twinning plane. This would require for $\beta=90°\ 28'\ 34''$ (Scharizer's value for the inclination of the a and c axes) a salient angle along the twinning line on the base of 180° 57′ which could not be detected. A section across the crystals, parallel to Scharizer's clino-pinacoid, should also show an inclined extinction which would be especially marked along the twinning limit; a section thus prepared shows perfectly normal orthorhombic symmetry in polarized light.

The optical properties point most decidedly to orthorhombic symmetry. The obtuse bisectrix is normal to the basal plane, the plane of the optical axes is the brachypinacoid. The divergence of the optical axes measured with a large Fuess apparatus in the Thoulet solution ($n=1{\cdot}6503$ for yellow, Na, flame), is

$$2\mathrm{H}=101°\ 10' \text{ for yellow.}$$

Using Bertrand's mean index of refraction $\beta=1{\cdot}569$ we get

$$2\mathrm{V}=108°\ 42' \text{ for yellow.}$$

Bertrand determined $2\mathrm{V}=105°\ 8'$, and Scharizer $2\mathrm{V}=108°\ 31'$. The dispersion about the obtuse bisectrix is marked $\rho > v$ and therefore about the acute bisectrix $\rho < v$. A section parallel to the macropinacoid showed the acute bisectrix in the

polarizing microscope but it was too small and fragile to transfer and use in the axial angle apparatus The acute bisectrix is axis of greatest elasticity and the double refraction is therefore negative.

The hardness of the crystals is 6–7. They scratch feldspar readily, and with care can be made to scratch quartz, though they are apt to crush owing to their small size and good cleavage.

The specific gravity, taken with the Thoulet solution, is 2·598. Bertrand found 2·593, Damour 2·586, and Scharizer 2·55.

By sacrificing all but one of the small crystals and scraping off the remnants of broken crystals from the quartz I succeeded in obtaining 0·1259 grams of material which floated on the Thoulet solution at 2·610 and sank at 2·551 sp. gr. This was subjected to a very careful chemical analysis with the following results:

	Penfield.	Damour.	Theory for $H_2Be_4Si_2O_9$.
SiO_2	51·8	49·26	50·42
BeO	39·6	42·00	42·02
CaO	1·0		
H_2O	8·4	6·90	7·56
Fe_2O_3		1·40	
	100·8	99·56	100·00

The analysis is satisfactory considering the small quantity of material at my command. The BeO which was precipitated with ammonia was free from alumina and gave the characteristic beryllium reactions. The mineral lost 0·5 per cent by drying at 100° C. and 1·40 per cent at a faint red heat. The water in the analysis is too high, and probably part of it does not belong to the composition of the mineral. The microscopic sections show liquid inclusions, which are not CO_2 and are probably water, which may account for some of the excess.

It is probable that further search at Mt. Antero will yield more specimens of this mineral and better material for study. It is interesting to find this rare mineral in America along with the phenacite and beryl.

In closing I take especial pleasure in expressing my thanks to Mr. W. B. Smith for giving me the specimen for carrying on this investigation.

Mineralogical Laboratory, Sheffield Scientific School, May 14, 1888.

ART. VIII.—*Some Localities of Post-Tertiary and Tertiary Fossils in Massachusetts;* by W. W. DODGE.

IN 1851, Mr. William Stimpson described an occurrence of fossils at Point Shirley, on the north side of Boston harbor. A list of species was given, and it was noted that the most common of the fossils were deep water and northern forms.*

Not quite a mile north of the hill which appears to have been referred to, stands Winthrop Head, a hill about 105 feet high, as determined by the Coast Survey. It seems to have had formerly an oval base with its longer diameter directed a little north of west and south of east, but has lost nearly half its mass owing to the action of the sea at its eastern foot. Its southern slope is somewhat steeper than the northern. It has been mentioned as one of the lenticular hills of the vicinity, —a mistake easily made, for much of that portion of the material of the hill formerly exposed is hard, compact, blue clay with little indication of bedding.

About five years ago a railroad was built around the eastern foot of the Head, and the excavations required to make room for it above tide-level gave a vertical exposure of some feet in thickness of the lower strata composing the hill.

The lowest bed cut into (exposed to a little below the railroad grade), was somewhat arched, and consisted of loose, clean, rather fine gravel filled with small fragments of shells. *Venus mercenaria* and *Cardium Islandicum* (?) were the only shells identifiable with any reasonable degree of certainty among the fragments.

Above this gravel or sand, succeeded a hard, clayey gravel containing larger fragments. *Venus mercenaria* and *Mya arenaria* were most abundantly represented. Single specimens of *Cardita borealis*, *Tapes fluctuosa* (?) and a small gasteropod somewhat resembling *Lacuna neritoidea* completed the list of fossils observed during a short stay at the spot. This notice of the locality has been delayed from year to year in the hope of adding to the enumeration.

Higher up on the bluff, the stratification in the hard, blue clay soon becomes completely obscured, but bits of shell may be seen embedded here and there in places where running water furrows the slope and leaves projecting ridges of material undisturbed in position. Above the blue clay, red gravel forms the upper portion of the hill.

Most of the thirteen species named by Mr. Stimpson as occurring at Point Shirley have also been found as fossils else-

* Proceedings of the Boston Society of Natural History, vol. iv, p. 9.

where in New England, about half of them at Nantucket. According to the assignment of synonymy and distribution in Messrs. Verrill, Smith and Harger's catalogue* six of the species now extend southward to Florida, one each to the Carolinas, three to New Jersey, one (common north of Cape Cod), does not appear in Vineyard Sound; in the other direction, three reach the Arctic ocean, one Greenland, three Labrador, two the Gulf of St. Lawrence, three Massachusetts Bay. Two remain below low-water mark, one is almost confined to sandy places; a large majority may be found in the colder waters of the ocean shores as well as in the bays, etc., but three prefer the sandy or muddy shores and bottoms of sounds, bays and estuaries. *Venus mercenaria* is of this last group. The apparent prominence of this species at Winthrop Head is doubtless partly referable to the solidity of its shell and the consequent endurance of the same in recognizable form where other shells were broken up or decayed.

Tertiary of Southeastern Massachusetts.

The dredging for the Cape Cod canal in Sandwich has brought up fragments of bone similar to those found at Gay Head. No published notice of this fact has come to the writer's attention. It is to be hoped that the opportunity for observation has been or will be duly utilized by some one in the interests of science.

ART. IX.—*A Cordierite Gneiss from Connecticut;* by E. O. HOVEY.

CORDIERITE, or iolite, has long been known to occur at Haddam, Ct., where it is found "associated with tourmaline in a granitic vein in gneiss." It has also been reported as being abundant in quartz in the gneiss north of Norwich, Ct., and at Brimfield, Mass. No true cordierite gneiss, however, has heretofore been reported from this country. A gneiss of this kind was recently found by the writer in the town of Guilford, sixteen miles east of New Haven, while in search of garnets and vesuvianite. The outcrops begin on the western side of a hill 375 ft. east of the Guilford-Durham turnpike, about two and a half miles north of the railway station on the farm of Richard Woodruff; the line of ledges was traced for a fifth of a mile. The general course of the ledges is N. 15° W. (true), while the strike of the bedding of the rock seems to be N. 25° W., which gives them a calculated aggregate

* Report upon the Invertebrate Animals of Vineyard Sound, etc., 1874.

width of more than 175 feet. Their vertical faces are from five to fifteen feet in height. The cordierite is more thickly disseminated through the rock, and is in larger grains in the southern ledges than it is in the northern. The rock is composed of biotite, quartz, and cordierite, with some plagioclase. In the hand specimen the cordierite has a deep blue color, and shows its characteristic dichroism plainly. In a thin section it is clear and almost free from alteration, has a delicate violet tint which readily escapes detection, and is without perceptible dichroism. No optical characters other than those noted by Rosenbusch were observed. Acicular inclusions of sillimanite are abundant, but they are arranged without apparent accordance with any law. They serve as a convenient means of distinguishing most of the cordierite from the quartz, which it closely resembles. The axial figure is excellent and is easy to get.

A few rods west of the line of ledges of cordierite gneiss, and with the same general course, there is a ledge of hornblende schist and gneiss containing numerous veins of garnet associated with vesuvianite of a dark green color. The vesuvianite occurs massive in the veins, showing few crystalline planes and those mostly prismatic. The garnet also is massive, but it shows many crystalline points of clear material; its color is yellowish red, and its appearance entirely different from that of the deep red individual garnets which are so common in the gneiss. The latter usually show the 2-2 planes most prominently, while in the former the *I* planes modified by the 3-$\frac{3}{2}$ predominate. The veins vary from half an inch to four inches in width, coincide with the bedding of the gneiss, and are seen for only 100 feet on the east side of a ledge but fifty feet wide. No cordierite was found in this ledge. Many garnets of value as gems have been taken from the ledge in the last six years. A quarter of a mile northeast of this point coarse black tourmalines occur in a vein in quartz.

Percival puts the gneiss of this region into his "Anthophyllite Formation," which includes the famous Haddam locality, about fifteen miles northeast of the locality here described.

Magnetite in good octahedral crystals $\frac{1}{3}$ in. to 1 in. in diameter occurs in the school district of Nut Plains, town of Guilford. The locality has long been known to the inhabitants of the district. It is a ledge of gneiss on the north side of the North Madison road, half a mile east of the Nut Plains school house. The ledge is a few rods east of a ruined farm house and near a large brook.

Yale University, May 28th, 1888.

Art. X.—*The Flow of Solids: A Note;* by William Hallock.

The justice of Mr. Spring's* protest against a part of my original paper I am glad to admit, as far as it concerns an ill-advised use of terms, and a consequent misrepresentation of his views, of course entirely unintentional. Not realizing that many were not so familiar with Mr. Spring's works as myself, I neglected in the brief paper to give his views, and thus my deductions from his results seemed to represent his own conclusions.

The object of my original investigation† was a solution of the question whether pressure alone is capable of producing true liquefaction; many have certainly believed so, or even do believe so, and a few, at least, including myself saw in Mr. Spring's earlier results evidence of such a possibility. I believe that to produce such phenomena, as some recrystallizations, and diffusion, an increase in the freedom of motion of the molecule, an increased diffusibility, i. e., the beginning of a liquefaction, is indispensable. Hence I looked upon his results as pointing to a liquefaction by pressure. My own experiments with the same substances and pressures showed the impossibility of liquefying them by pressure and even brought out an enormous increase in the rigidity of beeswax and paraffin under such pressures.‡ In concluding I wished only to call attention to the difference between Mr. Spring's *results* and my own, but unfortunately a loose and abbreviated quotation caused the misunderstanding, which I wish to explain.

Since obtaining my own results there seems to me little doubt that many, at least, of Mr. Spring's effects are caused rather by a *motion under pressure*, a kneading, as it were, and by the regrinding. The holders in which his compressions were made were not tight and the most perfect welding§ always took place at the surface of the block, or the corners, or where the material was forced into the cracks, often even while the center, under equal pressure, remained almost unaffected. My holders were tight, allowing no leaking or motion, and the substances showed scarcely a trace of a welding under pressure. I must therefore reiterate that which I wished originally to impress, namely that the majority of Mr. Spring's results are not produced by simple cubic static pressure.

In the cases of chemical action and the formation of alloys, I believe that the *motion under pressure* will be found to be the all important factor, perhaps just as stirring assists diffusion to com-

* W. Spring, this Journal, xxxv, 1888, p. 78, also Bull. de l'Acad. R. Belg., xiv, 1887, p. 585.

† W. Hallock, this Journal, xxxiv, p. 277, 1887.

‡ Compare also Ordnance Dep't Tests of Metals, etc., 1884. Gov't Printing Office.

§ W. Spring, Bull. d. l'Acad. R. Belg., xlix, p. 352, 1880. *Phosphore amorphe* et seq.

pletely mix two liquids. Even if blocks of barium sulphate and of sodium carbonate* were brought into actual chemical contact, I think no one would expect that simple diffusion would complete the interchange of bases and acids in finite time so long as both substances remained solid ; nor that a piece of copper and of tin soldered together would diffuse and form a homogeneous bronze ; nor would they expect that simple cubic static pressure would promote these reactions ; if pressure will assist them to completion, it will increase the diffusibility of solids, increase the freedom of motion of their molecules, that is, it will make them more like liquids, will begin to liquefy them.

I wish to refer here to a new law I recently proposed† concerning the formation of alloys, where the fact is brought out that the melting point and liquidity of the product are quite as important as those of the constituents in determining the possibility of a reaction. Mr. Spring‡ has produced Wood's alloy by compressing the constituents together, and quotes Mr. Romna§ as having failed to obtain fine platinum wire by electro-silver-plating a platinum wire, drawing it down and dissolving off the silver in nitric acid, because the silver and platinum alloyed under the pressure of the draw plate. Messrs. W. & L. E. Gurley, of Troy, N. Y., have for several years made fine platinum wires by the well known Wollaston‖ method of *casting* silver around the platinum and treating as above. In the note referred to† I have described the production of Wood's alloy *without pressure at* 100° C. of a tin-lead alloy at 190° C. of the sodium-potassium alloy at ordinary temperatures, etc. Hence it appears to me that pressure alone is the least important factor in the production of the effects obtained in Mr. Spring's investigation.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Modern Theories of Chemistry;* by Dr. Lothar Meyer. Translated from the German (5th edition) by P. Phillips Bedson, D. Sc., etc., and W. Carlton Williams, B. Sc., etc. 8vo., pp. xliv, 588. London, 1888. (Longmans, Green & Co.) The present English edition of Lothar Meyer's excellent book will be warmly welcomed by American chemists, to many of whom it is already well known in the original. No better evidence of the high appreciation in which it is held abroad can be given than the fact

* W. Spring, Bull. Soc. Chem., xliv, p. 166, 1885.

† W. Hallock, Science, Mar. 2, 1888, xi, p. 100, also Ostwald. Zeitschr. f. Phys. Chem., vol. ii, 1888.

‡ W. Spring, Ber. der deutsch. Chem. Gesell., xv, p. 595, 1882. § Ibid.

‖ Ganot's Physics, Atkinson, New York, p. 76, 1883.

that a fifth edition has been called for so soon after the fourth was issued. In the first edition, as the author tells us, the chief aim was to show not only that hypotheses and the theories based upon them are necessary aids to chemical investigation, but at the same time to assign to them their true value and to place them in a position similar to that which they occupy in theoretical physics. But this aim was an ephemeral one since it was local in time. The fourth edition was therefore completely revised and rewritten so as to give an account of the latest development of chemical theories and at the same time, by giving the more important empirical data, to make the theoretical conclusions arrived at easier to follow and to render clearer the causes leading to their foundation. This edition was divided into three books; the first dealing with atoms and their properties, the second with the Statics of the atoms or the doctrine of the equilibrium of the atoms in their combinations with one another, and the third with the Dynamics of the atoms or the doctrine of chemical change. With reference to the title the author says: "I do not in the least agree with the use of the term '*modern*' when referring to '*chemistry*' but only as I have used it in reference to the '*theories*'; for in my opinion no change has been effected in chemistry in the last hundred years, with perhaps the single exception of the passage from the phlogistic to the antiphlogistic system, which has been of so revolutionary a character as to justify a line of demarcation between an old and a new or modern chemistry." The fifth edition differs from the fourth chiefly in the use of atomic weights recalculated by the author and Dr. Seubert, in certain abridgments in the second book, and in certain changes in the third book, particularly relating to the thermal phenomena accompanying chemical action and to the action of mass. The sections now found in Part First treat of "The Atomic Hypothesis," "The Specific Gravity of Gases as an aid to determine Atomic Weights," "Determination of Atomic Weights by the aid of the Specific Heat in the Solid State," "Determination of Atomic Weights by aid of Isomorphism," and "Chemical Atoms." Those in Part Second are: "Forms of Combinations of the Atoms; Types," "Law of Atomic Linking," "Molecular Weight and Atomic Linking of those Bodies to which Avogadro's law cannot be applied," and "The Chemical Value, Valency, or the Capacity of Saturation of the Atoms." The sections in Part Third are: "Chemical Change and its Causes," "Chemical Change produced by Mechanical Disturbance," "Heat as Cause and Effect of Chemical Change," "Influence of Mass on Chemical Action," "Chemical Action of Light," "Chemical Change as a Cause and Effect of Electricity; Electrolysis," and "Stability of Chemical Compounds." These subjects are treated with the ability and thoroughness characteristic of the author, who has himself contributed so largely by his own investigations to establish some of the most important conclusions reached. So that as a whole the book seems to us one of the most important chemical

publications which has appeared in recent times. We think the time has come however for using the terms "atomic mass" and "molecular mass" in place of atomic weight and molecular weight. It would accord with present practice too, if density were given in absolute measure instead of being referred to the air standard. The translation is one of rare excellence and Dr. Bedson and Mr. Williams deserve the thanks of English-speaking chemists not only for producing Dr. Lothar Meyer's book in its English dress but for presenting it in so acceptable a form. The mechanical execution of the book is excellent.

G. F. B.

2. *On an Experiment to illustrate Valence.*—LEPSIUS has contrived a lecture apparatus for demonstrating the valence of the metals, based upon the method adopted by Nilson and Petterson to determine the atomic weights of the rare elements; i. e., heating a weighed quantity of the metal in dry hydrogen chloride gas and measuring the hydrogen set free. In a combustion tube 40^{cm}. long, pieces of thallium, of zinc and of aluminum are placed, about 10^{cm} apart; the weight in each case corresponding to double the atomic weight in milligrams; i. e., 408^{mgrms} thallium, 113^{mgrms} zinc and 54^{mgrms} aluminum. The hydrogen chloride is evolved by the action of strong sulphuric acid on a piece of ammonium chloride and is carefully dried by passing it through sulphuric acid. The hydrogen is collected in an apparatus like a Hofmann apparatus for decomposing water, but which has three graduated tubes, the whole rotating in a socket containing mercury so that the gas may be sent into either of the tubes at will. The three tubes are filled with a dilute soda solution. In performing the experiment the thallium is first heated with a Bunsen burner and the hydrogen collected in one of the three tubes. Then the zinc is similarly heated and after that the aluminum, the evolved gas being collected in the second and third tubes. The hydrogen in the first tube will occupy $22{\cdot}32^{cc}$, that in the second $44{\cdot}62^{cc}$, and that in the third $67{\cdot}86^{cc}$; the ratio of the three being 1 : 2 : 3, or that of the valence of the metals used.—*Ber. Berl. Chem. Ges.*, xxi, 552–561, Feb., 1888. G. F. B.

3. *On the action of Hydrogen sulphide on Arsenic acid.*—The action of hydrogen sulphide on arsenic acid has been studied by BRAUNER and TOMICEK. They conclude: 1st, that, other things being equal, more arsenic pentasulphide is formed (*a*) the larger the quantity of hydrochloric acid present, (*b*) the larger the quantity of hydrogen sulphide put into the solution in a unit of time, and (*c*) the lower the temperature (between 0° and 100°); and 2d, that, in consequence of the reducing action of the hydrogen sulphide, more arsenic trioxide is formed (*a*) the less hydrochloric acid there is present, (*b*) the smaller the quantity of hydrogen sulphide and (*c*) the higher the temperature. Hence when a rapid current of hydrogen sulphide is passed into a solution of arsenic acid arsenic pentasulphide alone is formed, though but slowly if free hydrochloric acid is present and the liquid is kept warm.—*J. Chem. Soc.*, liii, 145–159, Feb., 1888. G. F. B.

4. *Elements and Meta-elements.*—In his annual address as President of the Chemical Society, Mr. CROOKES has continued the discussion upon the nature of the elements which he began in his address at Birmingham. What is the criterion of an element, and how is the line to be drawn between identity and distinct existence? Oxygen, sodium, sulphur, chlorine, are concededly separate elements; and so are chlorine, bromine and iodine. But even here degrees of "elementicity" may be assumed, since chlorine is much closer to bromine than it is to oxygen, sodium or sulphur. Nickel and cobalt rank as distinct elements; but would this have been the case had their compounds been identical in color? Passing to the rare earth elements, the ground under our feet is less secure. Even if scandium, ytterbium, etc., be admitted to the list of elements, what can be said for neo- and praseo-didymium, whose chief chemical claim to individuality is certain slight differences in basicity and crystallizing power, though their physical differences spectroscopically are well marked. If we admit these, how can we exclude the series of bodies discovered by Krüss and Nilson, or those into which yttrium, erbium, samarium, etc., have been and are being split up? Here "the different groupings shade off so imperceptibly the one into the other that it is impossible to erect a definite boundary between any two adjacent bodies and to say that the body on this side of the line is an element, whilst the one on the other side is non-elementary, or merely something which simulates or approximates to an element." "Slight chemical differences, of course, are admitted, and, up to a certain point, so are well-marked physical differences. What are we to say, however, when the only chemical difference is an almost imperceptible tendency for the one body—of a couple or of a group—to precipitate before the other? Again, there are cases where the chemical differences reach the vanishing point, although well-marked physical differences still remain. Here we stumble on a new difficulty: in such obscurities, what is chemical and what is physical? Are we not entitled to call a slight tendency of a nascent amorphous precipitate to fall down in advance of another a 'physical difference?' And may we not call colored reactions depending on the amount of some particular acid present and varying according to the concentration of the solution and to the solvent applied 'chemical differences?' I do not see how we can deny elementary character to a body which differs from another by well-marked color- or spectrum reactions, whilst we accord it to another body whose only claim is a very minute difference in basic powers." In answer to the question, how minute differences qualify a substance to be admitted as an element, the author classifies them as follows: (1) Two closely allied substances differing slightly in basic powers and more decidedly in spectrum reactions; such as erbium and holmium, erbium and yttrium; samarium and didymium; these are probably chemical entities. (2) Two substances which, like the white and yellow components of

cerium, have no distinct spectrum reaction and differ in basicity so slightly that their separation has not been possible, and yet have differently colored oxides; these the author would concede to be elements. (3) Two substances, obtained from different minerals, which have no recognizable chemical differences, but the phosphorescent spectrum of one having a strong line which is absent in that of the other; as the yttria from samarskite and that from gadolinite. (4) An earth like yttria or samaria having a definite phosphorescent spectrum, and which is separable only with enormous difficulty from its associates, but to which the addition of another substance greatly intensifies one or more of the lines of its spectrum, the others remaining unaffected. Is such an earth simple or compound? (5) An earth which, like calcium sulphate, showing no difference on fractionation, has a phosphorescent spectrum not materially modified by admixture, but the residual glow of one part of which is suppressed as seen in the phosphoroscope, while the rest is unaffected. (6) Earths, like yttrium obtained from different minerals, which behave alike both chemically and spectroscopically, except that in the spectrum of the one a certain line is a little brighter than it is in that of the other. The difficulty arising from the periodic theory, Mr. Crookes obviates by suggesting the use of the term, "elementary group" for "element." "Let us say, e. g., the smallest ponderable quantity of yttrium is an assemblage of ultimate atoms almost infinitely more like each other than they are like the atoms of any other approximating element. It does not necessarily follow that the atoms shall all be absolutely alike among themselves. The atomic weight which we ascribe to yttrium therefore merely represents a mean value around which the actual weights of the individual atoms of the 'element' range within certain limits. But if my conjecture is tenable, could we separate atom from atom we should find them varying within narrow limits on each side of the mean." Considering the process of fractional precipitation, as when to a dilute solution of yttrium, dilute ammonia is added in quantity sufficient to precipitate only half of the yttria, "the problem is not *why* a precipitate is produced, but *what determines* or directs some atoms to fall down and others to remain in solution. Out of the multitude of atoms present, what power is it that directs each atom to choose the proper path? We may picture to ourselves some directive force passing the atoms one by one in review, selecting one for precipitation and another for solution till all have been adjusted. In order that such a selection can be effected there evidently must be some slight differences between which it is possible to select, and this difference almost certainly must be one of basicity, so slight as to be imperceptible by any test at present known, but susceptible of being nursed and encouraged to a point where the difference can be appreciated by ordinary tests." To make clearer this deviation from absolute homogeneity, the author goes back to the earliest dawn of the material universe, finds "an infinite

number of immeasurably small ultimate or rather ultimatissimate particles gradually accreting out of 'formless stuff,' and moving with inconceivable velocity in all directions. We find those particles which approximately have the same rate and modes of movement beginning to heap themselves together by virtue of that ill-understood tendency through which like and like come together." One of the first results of this massing tendency is the formation of certain nodal points in space, between which occur approximately void intervals. The first step in differentiation having been achieved, the ultimate particles have commenced to vibrate in their new-born energy in all directions and with velocities ranging from zero to infinity. "The slower particles will obstruct the quicker, the more rapid will rush up to the laggards in front, and we shall soon have groups forming in different parts of space. The constituents of each group whose rate of vibration is not in accord with the mean rate of the bulk of the components of that group will work to the outside and be thrown off, to find other groups with which they are more in harmony. In time, therefore, a condition of stability is established between the various groups, and we may call these the molecules of our present system of elementary bodies." Supposing the constituent atoms of these molecules not to have been gifted originally with exactly the same speed or amplitude of vibration, they will form a group, collected around the mean value, these groupings representing what are at present called elements, but which the author conjectures may be made up, each of an element and of a certain number of meta-elements, or each of a whole group of meta-elements. In considering the question of periodicity, Mr. Crookes modified somewhat the diagram of his Birmingham address. There the action of the two forces upon the original protyle was pictured, "one being time, accompanied by a lowering of temperature; the other, swinging to and fro like a mighty pendulum having periodic cycles of ebb and swell, rest and activity, being intimately connected with the imponderable matter, essence or source of energy we call electricity." In order to introduce the third factor, space, into the diagram, a tri-dimensional curve is required; and since the curve must pass through a point neutral to electricity and chemical energy twice in each cycle, a curve is selected which fore-shortens vertically into a zig-zag, and horizontally into a lemniscate. Projecting this curve in space, the points where chlorine, bromine and iodine are formed come close under each other. The same is true of sulphur, selenium and tellurium, and also of phosphorus, arsenic and antimony. "Let us imagine a cyclical translation in space, each revolution witnessing the genesis of the group of elements previously represented as produced during one complete vibration of the pendulum. Let us suppose that one cycle has thus been completed, the center of the unknown creative force in its mighty journey through space having scattered along its track the primitive atoms, the seeds which presently are to coalesce

and develop into the groupings now known as lithium, beryllium, boron, carbon, nitrogen, oxygen, fluorine, sodium, magnesium, aluminum, silicon, phosphorus, sulphur and chlorine." "Suppose the *vis generatrix* traveling to and fro in cycles along a lemniscate path as above suggested, while simultaneously temperature is declining and time is flowing on; each coil of the lemniscate track crosses the same vertical line at lower and lower points. Projected in space, the curve shows a central line neutral as far as electricity is concerned and neutral in chemical properties—positive electricity on the north, negative on the south. Dominant atomicities are governed by the distance east and west from the neutral center line, monatomic elements being one remove from it, diatomic two removes, and so on. In every successive coil, the same law holds good. As the mighty focus of creative energy goes round, we see it in successive cycles sowing in one tract of space seeds of lithium, potassium, rubidium and cæsium; in another tract, chlorine, bromine and iodine; in a third, sodium, copper, silver and gold; in a fourth, sulphur, selenium and tellurium; in a fifth, beryllium, calcium, strontium and barium; in a sixth, magnesium, zinc, cadmium and mercury; in a seventh, phosphorus, arsenic, antimony and bismuth; in other tracts, aluminum, gallium, indium and thallium; silicon, germanium and tin; carbon, titanium and zirconium; whilst a natural position near the neutral axis is found for the three groups of elements relegated by Professor Mendeléjeff to a sort of hospital for incurables—his eighth family." "We have now traced the formation of the chemical elements from knots and voids in a primitive formless fluid. We have shown the possibility—nay, the probability—that the atoms are not eternal in existence, but share with all other created beings the attributes of decay and death. We have shown from arguments drawn from the chemical laboratory, that in matter which has responded to every test of an element there are minute shades of difference, which may admit of selection. We have seen that the time-honored distinction between elements and compounds no longer keeps pace with the developments of chemical science, but must be modified to include a vast array of intermediate bodies—'meta-elements.' We have shown how the objections of Clerk-Maxwell, weighty as they are, may be met; and finally, we have adduced reasons for believing that primitive matter was formed by the act of a generative force throwing off at intervals of time atoms endowed with varying quantities of primitive forms of energy."—*J. Chem. Soc.*, liii, 487, May, 1888. G. F. B.

5. *Measurement of High Potential.*—Quadrant electrometers, it is well known, are not suitable for the measurement of high potential. A. VOLLER enters into a full discussion of the faults inherent in the various methods of connecting the parts of the Thomson electrometers with the sources of electricity, and finds these methods all unsatisfactory. He has been led, therefore, to adopt a new method. The needle of the electrometer is provided

with suitable magnets or pieces of iron, which are controlled by a movable magnetic field, the strength of which can be suitably altered by moving these magnets beneath or in the neighborhood of the needle. The needle of the electrometer was connected to earth, and the quadrants were alternately connected to the source of electricity. In this way a deflection was produced by induction, and if s and s' are deflections, and V and V′ potentials, we have $s : s_{\prime} = V^2 : V_{\prime}^2$. The changeable magnetic field gives the instrument a great range.—*Ann. der Physik und Chemie,* No. 6, 1888, pp. 286–298. J. T.

6. *Fluorescence.*—It is known that the fluorescence of liquids increases very greatly to a certain point with the dilution of the fluorescing medium. B. WALTER discusses the reason of this phenomenon, and shows that it depends upon the amount of light absorbed by the fluorescent substance. Strongly fluorescing substances, like magdala red, eosine, chlorophyl, etc., in the solid state, show no fluorescence, and the author believes that fluorescence hitherto observed in solid bodies can be traced to water of crystallization or other thinning medium. If A denote the amount of light absorbed by the substance, Fl the amount of light emitted by fluorescence, the fraction Fl/A can denote the fluorescing power of the medium. In the case of eosine, with a dilution of $\frac{1}{8}$, the value of this fraction was ·000663; with $\frac{1}{2048}$ its value was ·009126.—*Ann. der Physik und Chemie,* 1888, No. 6, pp. 316–326. J. T.

7. *Grünwald's hypothesis in spectrum analysis.*—Dr. A. GRÜNWALD continues to give the results of his remarkable hypothesis and reserves to a later paper the description of the steps by means of which he obtains certain relations between groups of spectral lines. In his paper to which this notice refers, will be found a number of numerical results. Oxygen he thinks is composed of a substance A′ combined with another substance O′; this substance O′ being a compound with the formula $b_4O''_5$; where O″ is again a compound b_4c_5; so that $O = H'b_4(b_4c_5)_5$. He had previously shown that, according to his hypothesis, hydrogen is composed of two primary elements, *a* and *b*; and now gives various criteria by means of which *a*, *b* and *c* can be recognized in magnesium and carbon.—*Phil. Mag.,* May, 1888, pp. 343–350. J. T.

8. *Penetration of Day-light in the water of Lake Geneva and of the Mediterranean.*—MM. FOL and SARASIN give a summary of the results obtained by them in regard to the penetration of day-light in clear water. They employed sensitive photographic plates, so arranged with a new apparatus, that they could be exposed for the time selected, say ten minutes, at any desired depth, as 100, 200 or 300 meters, etc. In the first trials made it was found that the effect was stronger on September 28th, with a cloudy sky, than on August 16th, with fine weather; more particularly they found that in the former month the amount of light at a depth of 170 meters was comparable to that

of a clear night without moon. The extreme limit for the penetration of day-light during the winter was something more than 200 meters. The difference between this limit for March and September was only some 20 or 30 meters, proving that the effect of the seasons, so great in the upper layers of the lake, as shown by M. Forel (this Journal for June, p. 495), is comparatively small at considerable depths. In the Mediterranean, the depth is greater. In the month of March it was found here that 400 meters was the limit of transmission of day-light. Further, subsequent experiment showed that at 300 meters the light reaches during the whole time that the sun is above the horizon and at 350 meters this is true for some eight hours of the day.—*Bibl. Univ.*, III, xix, 442–447.

9. *A Treatise on Electricity and Magnetism;* by E. Mascart and J. Joubert, translated by E. Atkinson. Vol. ii, 792 pp., 8vo. London, 1888 (Thos. de la Rue and Co.).—The first volume of the English translation of this excellent work appeared some four years since (this Journal, xxvi, 148). The present volume goes through the subjects of methods of measurements and their applications, treating them with admirable thoroughness and system. The general methods of measurements are first taken up and then the special subjects of the theory and use of electrometers, galvanometers and other electrical instruments; followed by magnetic measurements. A concluding chapter discusses the industrial applications as involved in electrostatic machines, dynamos, motors, etc.

II. Geology and Mineralogy.

1. *Geological Survey of Ohio: Economic Geology.* Vol. VI, 832 pp., 8vo.—Six hundred pages of this report are devoted to the subject of petroleum and natural gas; and three-fourths of these are by Professor Edward Orton; the other fourth, consisting of accounts of the methods of drilling wells, measurement of wells, transportation, uses of gas and methods of using, and other subjects of a practical character, are by Messrs. F. W. Minshall, F. H. Newell, E. McMillin and Professor S. W. Robinson. The remaining chapters treat of the Pittsburgh Coal-Seam, salt manufacture, cements, gypsum or land plaster, lime, and includes also one on the Drift deposits of Ohio.

Professor Orton opens with a new vertical section of the Ohio rocks. The Trenton limestone is here recognized as one of the outcropping rocks, Professor Orton accepting the conclusion of Mr. S. A. Miller, that the beds of the Point Pleasant quarries, about 20 miles above Cincinnati, are Trenton. Besides, the Utica shale is separated by fossils from the Hudson River group, and the term Cincinnati group is dropped.

The form of the Cincinnati anticline, long since shown by Newberry to have been made before the deposition of the Upper Silurian, has been worked out by the numerous borings for gas

and oil, and is well exhibited on a map facing page 48, giving the depths at which the Trenton limestone lies buried. Along the Ohio near Cincinnati the depth is about 300 feet *above* tide-level, and 150 miles east of north, 20 miles from Lake Erie, it is near 500 miles *below* it. Tide-level is passed by its upper surface about 40 miles north of Cincinnati. The mean pitch for the whole 150 miles is 1 to 1000. For the first 40 miles it is 1 : 700; for the next 75 miles, Eaton to Lima, or 85 miles, from Eaton to Beaver Dam, nearly 1 : 1000. About the Beaver Dam region, a bending up of the beds of the anticline occurs, and there is a *rise* in the next 24 miles from 310 to 350 feet below tide-level; and the region at this point is that of FINDLAY. A dozen miles beyond Findlay the northern dip of the anticlinal is resumed, but its position is changed a little to the eastward of the previous course; and in the next dozen miles there is a fall of 50 to 90 feet, or to 400 feet below tide-level; but 3 miles beyond this, at Bowling Green (22 miles from Lake Erie), the depth obtained is only 387 feet. Nearer the lake, in Ottawa County, the dip down increases much, the depth of the Trenton at Oak Harbor being 724 feet. East or west of the axial region of the anticline the dip is larger; westward, in the northwestern corner of the State, the depth becomes 1000 feet to 1500 or beyond, and the same is true to the eastward, the depth below tide-level at Port Clinton, only 14 miles from Oak Harbor, being 1079 feet below tide-level, showing a dip exceeding 1 in 300; and along the region southward to the Ohio, the depth increases and the overlying rock is mostly an Upper Devonian shale.

These levels are here cited because, as Professor Orton points out, they have a bearing on the gas-producing character of the region. Findlay is the center or most productive part of the Trenton limestone gas-supply; and, as is above shown, it is situated, like other localities of gas-production in western Ohio, along the axis of the anticlinal; but it has the advantage of being situated over the summit of an upward bend in the axial region. This summit region extends northward for 10 or 12 miles, so as to include also Van Buren and Bairdstown. The Findlay gas-wells—of which 16 out of 17 bored are productive—yielded in 1886 at the rate of 20,000,000 to 25,000,000 cubic feet of gas per day; and one, the Karg well, is credited with half the whole amount. The depth to which the stratum of Trenton limestone is usually penetrated is only 15 to 25 feet, though occasionally 50 to 60; much below this, comparatively little is obtained; and the depth from the surface of the country is 1100 to 1200, so that the expense of boring is small. A well at Van Buren even exceeds the Karg well; and one at Bairdstown is not inferior to it, for 9 feet down in the Trenton the supply was 4,000,000 cubic feet per day; at 17 feet, over 12,400,000 cubic feet and the tools "refused to descend deeper, dancing in the well like rubber balls." Bairdstown and Van Buren, as above stated, are in the same upward bend of the anticline and at nearly the same level.

Bloomdale, 3 miles east of Bairdstown, has a well yielding about 3,000,000; and one at North Baltimore, as far west of it, yields about the same amount; both less advantageously situated in the anticline for productiveness.

Professor Orton remarks on the fact that among the various wells in the gas region, the production is generally greatest where the depth below the sea level is least, that is, where the Trenton is bulged upward. This depth at the Karg well is 347 feet; at others of the more productive wells of the vicinity of Findlay, 342, 350, 328·8; at Bairdstown, 315 feet.

Another important fact established is that the Trenton limestone is productive only where it is dolomyte, not where calcyte. In the Findlay field the gas rock afforded Professor N. W. Lord, in one analysis, calcium carbonate 53·50, magnesium carbonate 43·05, insoluble residue (silica, etc.) 1·70, iron and alumina 1·72 = 99·50, in which the proportion of the two carbonates is almost precisely that of true dolomyte. The amount of marsh gas in the gas scarcely varies from 92·5 per cent, and with this there are about 2 per cent of hydrogen, 0·30 of olefiant gas and 3·50 of nitrogen, with not over 0·5 per cent of each, oxygen, carbonic acid, carbonic oxide and 0·2 of sulphuretted hydrogen.

In the region of Lima, the Trenton limestone yields oil; but the oil is inferior to the shale oil of the Macksburg region of eastern Ohio, in containing 0·553 per cent of sulphur, which is more than 20 times the amount in the Macksburg oil.

The report treats at length also of the Berea grit (Subcarboniferous) and of the Ohio shale (Upper Devonian) as sources of oil, and discusses at length the theories for the formation of the oil and its condition in the rocks. The chapters on cements, lime, plasters and other economical products from the rocks of the State also contain much of general interest.

2. *Fauna and Flora of the Trias of New Jersey and the Connecticut Valley.*—Dr. Newberry, in vol. vi of the Transactions of the N. Y. Academy of Sciences, states that the plants of these regions thus far obtained, excepting two, are identical with those of Virginia and North Carolina described by Fontaine. They include the species *Bajera Munsteriana* Sap., *Brachyphyllum gracile* Newb., *B. foliosum* Newb., *Cheirolepis Munsteri* Schenk, *Clathropteris platyphylla* Brongn., *Dendrophycus Triassicus* Newb., *Dioönites longifolius* Em., *Equisetum Rogersi* Schimp., *Loperia simplex* Newb., *Otozamites latior* Sap., and *O. brevifolius* Fr. Br. (both common in the Rhætic of Germany and France), *Palyssya diffusa* Em., *Schinoneura planicostata* Rogers.

The fishes are ganoids of the genera *Diplurus* Newb., *Ischypterus* Egt. (18 species), *Catopterus* Redf. (5 species), *Ptycholepis* Ag. (1 sp.), *Dictyopyge* Egt. (1 sp.), and *Acentrophorus* Trag. (1 sp.) The *Diplurus* was a cœlacanth 3 feet long, closely allied to *Holophægus* Egt. from the English Lias. A species of *Dictyopyge* has been described from the Keuper of Germany and an allied *Ptycholepis* from the Lias of Boll in Wurtemburg.

3. *Archæan areas of Northern New Jersey and Southeastern New York;* by N. L. Britton.—Prof. Britton, in his paper read before the A. A. A. S. in August, 1887, divides the Archæan of the New Jersey Highlands and Putnam County, New York, into (1) the massive group, including quartz-syenyte, granulite, and granite with little or no bedding; (2) the iron-bearing group; (3) the gneissic and schistose group. Another series of schists and limestone, including the crystalline schists of Westchester County, described, as Mr. Britton observes, by Professor J. D. Dana [so far as they are conformable to the limestone or dolomite of the region] as [probably] of Lower Silurian age, are stated to be for the greater part "unquestionably Upper Archæan." We look with great interest for the evidence for this very positive conclusion; others have held the opinion, but the evidence has never been published. The allusion to Prof. Dana's opposing evidence on the next page, shows that he has been misread.

J. D. D.

4. *Annual Report of the State Geologist of New Jersey for the year* 1887.—This report announces the near completion of the topographical survey of the State—a most important work, in which New Jersey is ahead of the other States, Massachusetts alone excepted.

5. *On an Archæan Plant.*—Graphite occurring in an Archæan limestone in many very thin parallel stripes one or more inches long and one to two lines wide has been described by Mr. N. L. Britton as the remains of an Archæan plant, which he has named *Archæophyton Newberryanum.* It is a natural query whether a carbonaceous limestone under pressure and in course of metamorphism might not become striped like the specimen.

6. *On the Organization of the Fossil Plants of the Coal Measures.—Part XIV. The true fructification of the Calamites;* by W. C. Williamson.—In this short memoir Prof. Williamson gives his reasons for still believing that the strobile described by him in 1869 from the Upper-foot coal in Strinesdale, near Saddleworth, Lancashire, not only was, as he then stated, the fruit of a true Calamites, but that it was the only one that had thus far been discovered. After waiting seventeen years additional specimens having the same structure at last came to light. These led him to reinvestigate the whole subject and to figure anew all the specimens in his cabinet. The chief reason for believing in the true Calamitean character of these specimens is that the peduncle of the strobilus presents in every case substantially the same essential characters as the stems of Calamites, the structure of which is very different from that of any of the other Carboniferous plants that have been made known. Although somewhat modified to adapt itself for the growth of the large sporangia of the higher portions of the spike, these peduncles still clearly exhibit the internodal canals and characteristic medullary cavity of Calamites, characters so distinctive as to make it extremely doubtful that they could have belonged to any other plant. The

great wonder is, considering the abundance of Calamites everywhere in the coal measures, that its fruits should be of such rare occurrence. It is needless to say that these fruits are strictly cryptogamic, and contain spores only. L. F. W.

7. *Einleitung in die Paläophytologie vom botanischen Standpunkt aus.* Bearbeitet von H. GRAFEN ZU SOLMS-LAUBACH. Leipzig, 1887.—This work, although it bears evidence of wide research and much original investigation, is nevertheless, to the working paleophytologist, something of a disappointment. What is needed is a logical and systematic presentation of the best results of all the numerous and widely scattered investigations into the meaning of the multiform structures and objects that have been studied and separately made known. Count Solms-Laubach has proved by this work that he possesses the qualifications for conducting such an enterprise, but has preferred, German fashion, to give it the form of an original investigation and a decidedly subjective stamp, for which he was not qualified by a life-long devotion to the subject, such as gives so great weight and value to the researches of Williamson, Renault, and Schenk. The book, moreover, lacks entirely the symmetry and evenness of treatment so much to be desired at this time in paleobotany, and plainly shows that its author was impelled rather by the impulse to probe to the bottom a few such questions as chanced specially to interest him, leaving other equally essential ones nearly or quite untouched. But it should not be inferred that this work is devoid of value. To him who desires to attack the problems of paleobotany it will be found to contain a thorough and exhaustive treatment of many of the most knotty and puzzling questions, and it has the great merit of furnishing a clear guide to the entire literature of every subject treated.

The interest manifested by so excellent a botanist in paleontology is a hopeful sign as tending to reconcile the two departments, and while there is danger that the recent appointment of Count Solms-Laubach to the botanical chair made so celebrated by De Bary may not leave him time to continue the work to which this book is confessedly only an "Introduction," the science of botany proper is to be congratulated on having in such a prominent place one who is fully capable of weighing the facts furnished by the geological history of plants. L. F. W.

8. *Das Anlitz der Erde* von EDUARD SUESS. Vol. ii, 704 pp., 8vo. Vienna, 1888. (F. Dempsky).—The first volume of the great work by Professor Suess, noticed in this Journal in 1884, 1885 (xxvii, 151, xxix, 418), covered, first, the discussion of the movements in the exterior crust of the earth and, secondly, of the mountain systems. The second volume, now published, is devoted to the great oceans, treating of them first geographically as at present developed, and later with regard to the extent of the seas during the successive geological periods, from the paleozoic down to the changes of level noted in historic times and more broadly with respect to the cause of the oceanic depressions. The different fea-

tures of the Atlantic and Pacific are treated of at length, with the consideration of the causes for these differences. The extended reading of Professor Suess has given him a large fund of facts to add to his own extended observations, for use in these discussions, and his method is so comprehensive and his style so attractive, that such a book as the present is at once to a high degree interesting and instructive.

9. *Chert.* — Dr. G. J. Hinde has examined microscopically chert from the Permo-Carboniferous strata of Spitzbergen, and has proved that the material consists in many parts of closely-packed sponge spicules, passing often into a nearly pure translucent chert. The bed at Tempelberg was about three feet thick and contains also "casts of Productus and possibly also of Spirifer." He figures the spicules from specimens of different localities, and pronounces the chert of organic origin. A siliceous schist associated with the chert, was largely made of siliceous sand but contained many sponge spicules. On Axel's Island the cherty beds are 870 feet thick; and in view of all the facts he has observed since he commenced his investigations of chert, he thinks it not extravagant to conclude that although so thick the whole is "due to the accumulation of the skeletal debris of siliceous sponges."—*Geol. Mag.*, June, 1888, p. 241.

10. *Dumortiérite from a new locality.*—MM. Michel Lévy and Lacroix announce the discovery of the rare aluminum silicate, dumortiérite, in the iolite of the gneiss of Tvedestrand, Norway, where it is associated with sillimanite. It is distinguished, as in other cases, by its pleochroism.—*C. R.*, cvi, 1546, May, 1888.

11. *Zircon from North Carolina.*—The recent demand for zirconium, for use in the arts, has led to a systematic effort to mine it in large quantities. Once regarded as a rare mineral, it has been found possible to obtain within six months twenty-five tons from the Green River mines, Henderson Co., North Carolina; the mining has been carried on under the charge of Mr. W. E. Hidden, who gives this information. It is also anticipated that the attempt soon to be made to obtain monazite in similar large quantities will be successful.

12. *Seventh Annual Report of the State Mineralogist of California for the year ending Oct.* 1, 1887; by William Irelan, Jr. 315 pp., 8vo. Sacramento, 1888.—This report is devoted to the subjects of petroleum, asphalts, natural gas, coals and building stones, and gives much valuable information as to their occurrence, method of working, use and so on. Much of the matter is contributed by W. A. Goodyear and A. H. Weber, field assistants to the State Mineralogist. The report closes with a catalogue of the Californian fossils, compiled by Dr. J. G. Cooper.

13. *Contributions to the Mineralogy of the Pacific Coast;* by W. Lindgren.—A description is given of a chromiferous chlorite related to kotschubeite, obtained from Green Valley, on the American River. It occurs in rosettes of thin hexagonal tables having a peach-blossom red color, and also in fibrous massive

forms. The crystals are twins, formed of six biaxial sectors. It is associated with ouvarovite and chromite. Hardness = 2, specific gravity = 2·69. An analysis by W. H. Melville gave:

SiO_2	Cr_2O_3	Al_2O_3	FeO	NiO	MgO	CaO	H_2O		
31·74	11·39	6·74	1·23	0·49	35·18	0·18	12·69 [a]	0·36 [b]	= 100·00

[a] Above 105° [b] At 105°

The result is interesting as showing a much larger percentage of chromium than has before been noted.—*Proc. Cal. Acad. Sci.*, II, i, Dec., 1887.

14. *Materialien zur Mineralogie Russlands* von N. VON KOKSCHAROW. Vol. x, pp. 1–96. St. Petersburg, 1888.—The veteran Russian mineralogist, whose labors for science received so cordial a recognition a year ago, on the occasion of the 50-year anniversary of the commencement of his active service, has recently published the opening portion of the 10th volume of his Russian Mineralogy. The species treated of are clinochlore and kotschubeite, which receive an exhaustive revision, and in addition an extended abstract is given of the article on the remarkable meteorite of Nowo-Urei, by M. v. Jerofeieff and P. v. Latschinoff.

15. *Der Meteorit von Nowo-Urei*, von M. JEROFEIEFF und P. LATSCHINOFF in St. Petersburgh.—This meteorite, which fell September 22, 1886, near the village Nowo-Urei, Government of Pensa, Russia, is unique in containing carbon in the form of diamond. Three stones were known to fall, of which two were found. The external appearance did not differ from ordinary meteoric stones, and on the fracture they appeared of a dark gray color, and showed the presence of the chief constituents, olivine, augite and nickeliferous iron. In the course of the analysis, from 2 to 2·5 per cent of the material taken remained unattacked by acids, and of this, 60 per cent was amorphous carbon and 40 per cent resisted fusion in bisulphate of potash. The residue was in the form of light gray grains; it proved to consist of 89·6 carbon and 10·4 per cent ash, and had a specific gravity of 3·1; the hardness was sufficient to scratch corundum readily. It was consequently concluded that the substance must be ordinary diamond or the massive form carbonado. An analysis of the whole stone gave:

Fe(Ni)	Cr_2O_3	Fe_7S_8	C	Silicates	
5·47	0·95	0·43	2·26	90·76	= 99·87

The diamond-like carbon made up about 1 per cent of the whole. The silicates consisted essentially of olivine and augite in the ratio of 67·5 to 23·8. In amount of carbon this stone is exceeded only by that of Orgueil, which gave 4·1 per cent in form of a humus substance. As regards the occurrence of the carbon in the diamond form, the only related cases are those of the Arva iron, in which Haidinger found cubic crystals of a graphitic substance with apparently pyritohedral planes, and which Rose suggested might be pseudomorphs of graphite after diamond; and the related graphitic mineral cliftonite, from the meteoric iron of Youngdegin, W. Australia, recently described by Fletcher (this Journal, xxxiv, 232, 1887).

VI. Botany and Zoology.

1. *Recent advance in Vegetable Histology.* (*Second Paper*). A. *Researches on the Comparative Anatomy of Malvaceæ, Bombaceæ, Tiliaceæ, and Sterculiaceæ;* by A. Dumont, (Ann. Sci. Nat. ser. VII, vi, p. 129.)—At the close of a notice of Hitzemann's examination of Ternstroemiaceæ and allied families, and of Saupe's paper on the suborders of Leguminosæ, in the last number of this Journal, attention was called to the value of even the fragmentary and widely scattered results thus far obtained in this field of investigation. Every contribution to this department of study is a step nearer the position which must ultimately be occupied by systematic Botany before a satisfactory and comprehensive survey can be made of its entire domain. The papers of Chatin, Duval-Jouve, Bureau, and Vesque, have therefore a substantial value not only as contributions to Histology, but to classification as well. The same is true of the present paper by Dumont. It is to be regretted that it is not more copiously illustrated, since only four plates are devoted to more than one hundred pages of descriptive text. The general results reached by the investigator are essentially as follows,—*Malva,* especially *Malva oxyacanthoides,* realizes best the fundamental and primitive type; the secondary liber is very clearly stratified; its three zones contain numerous normal mucilaginous elements, both in the form of cells and of lysigenous receptacles. In plants of this family the members which have the same morphological adaptations have undergone similar modifications from the primordial type, and different species in genera of this order may be arranged to constitute a descending scale of degradation. At certain points where systematic Botany is in doubt, the gaps may be bridged over in this family by comparative histology. The group of families above mentioned forms a compact alliance and might be well placed under one natural order. Although the author has presented his observations clearly, it does not appear from such verification of his results as can be made by material now at hand, that it would be possible to exclude from his reconstructed order comprising the familes above mentioned, at least two outlying ones: if these two must be admitted, it would be difficult to say where our integration would or could be arrested.

One is impressed during the examination of this subject by the thought that a distinction like that which we make in the case of the organs of the plant between the parts which are in use and those which have lost or partially lost their office, should be followed out in the elements of the tissues. The suggestion of this which is given in the comparative Anatomy of Phanerogams and Pteridophytes, by the lamented DeBary, has not been kept so clearly in mind as it should have been, this is largely owing to the acknowledged difficulties which its application presents. The author of the paper under present consideration has unconsciously

made use of what we may fairly call one of the useless characters in his classification, namely, the striations and stratifications which belong to certain elements of these groups of plants. So far as these markings are mechanical in their nature, they are obviously to be classified among the useful modifications, but where they are slight, they appear to fulfil no important function, and hence can be used just as the stipules of Rubiaceæ are, for diagnostic characters. The same may be said of the characters of the elements of the pith. Lastly it must not be forgotten that every contribution to this subject adds to the records already at hand for the identification by the microscope of species, genera, and orders, of which only imperfect specimens are known.

B. *Researches on the origin and development of canals and receptacles for secretions;* by A. LeBlois. (Ann. Sci. Nat. ser. VII, vi, p. 247.—This subject is allied to the last. In canals and receptacles for secretion we have conspicuous organs which are widely diffused through the orders of flowering plants, and in some cases have distinctly biological offices of attraction, protection, and the like. But in some other familes, these organs are so much reduced that they can hardly be believed to subserve any important office, and in a few they exist as mere vestiges. Van-Tieghem has been successful in utilizing these organs for classificatory purposes in the case of Myrtaceæ, where he has applied what may be fairly called a quantitative method. Trécul and Müller have also devoted much attention to the examination of this important subject, but even yet comparatively little is known about the matter. This last contribution, by Le-Blois, adds many interesting details of an apparently trustworthy character, and gives also some results of physiological speculation. His conclusions may be given with little change in form. The tissues under consideration, are living (in distinction from those which, like tracheæ, have passed through their development and have become non-living), and they are always produced by division and separation, never by destruction and absorption of cells. Further, they are secreting tissues. They appear under two forms, the canal and the receptacle, in both cases generally surrounded by a protective sheath. The two forms are met with either isolated or conjoined. Proper receptacles for secretions are never met with in roots, but they are frequently observed in leaves. The secreting system is precocious in development, either in the embryo, as in some cases, or in parts arising later. G. L. G.

2. *The Botanical Works of the late George Engelmann. Collected for* Henry Shaw, Esq., *and edited by* William Trelease *and* Asa Gray. Cambridge, 1887.—This large quarto volume comprises the results of Dr. Engelmann's researches prosecuted during the scanty leisure of a laborious profession. His earliest paper relates to the morphology of plants, and brings out clearly the main principles which underlie the structure of Phanerogams. This was Dr. Engelmann's inaugural thesis and formed a fitting

introduction to fifty years of botanical activity. The examination of neglected and difficult groups of plants possessed a peculiar charm for this morphologist. Thoroughly grounded in the principles of morphology, he was able to make all of his work of the highest order. It was fitting that these valuable contributions should be brought together into a memorial volume. That this volume has been made entirely worthy of him whom it commemorates is due primarily to the affectionate appreciation of Dr. Engelmann's friend and neighbor, Mr. Henry Shaw, who has taken pride in lavishing expense upon this superb record of critical investigation. It is another proof, if indeed any were needed, of the sincere interest in scientific botany which is felt by the munificent founder of the Shaw School of Botany. To the editors belongs the credit of judiciously preparing the text for publication, by most careful collation. Since it is a memorial volume it has been left without editorial comment even at those points where comment might under other circumstances have been desirable.

3. *Excursions Zoologiques dans les Isles de Fayal et de San Miguel* (Açores), par JULES DE GUERNE. Campagnes Scientifiques du Yacht Monégasque L'HIRONDELLE. Troisième année, 1887.—The voyages of the Hirondelle are under the direction of S. A. le Prince Albert de Monaco, with the "collaboration" of Professor S. Pouchet, and have in view the study of the currents, life, etc., of the ocean. A stay at the Azores for some time in 1887 enabled M. J. de Guerne to study the life of some freshwater lakes of San Miguel and Fayal. The lakes of San Miguel are situated in the crater of Sete Cidades at the west end of the island. The crater is nearly circular, and has a longer diameter (W.N.W.-E.S.E.) of 5 kilometers, and the highest point around it is 846 meters above the sea. There are four lakes at the bottom, 3 kilometers square and less in size; three of them about 270 meters above sea-level and 22 to 30 meters in maximum depth. Two of them, Lagoa Grande and L. Azul, probably date from the year 1444, and a third from 1563. The Fayal lake cannot date back of the eruption of Capello in 1672. Hence the species that live in these lakes are of recent introduction.

The author describes critically and with many references to previous publications the freshwater and terrestrial species observed, noting their distribution elsewhere, and any peculiarities acquired, and describing many new species. The origin of the distribution of the species is next considered, and the following are the more important conclusions reached.

The terrestrial fauna of the Azores, is, as generally regarded, strongly European; and the freshwater fauna perhaps still more strikingly so. The species in the fauna are those of extremely wide distribution and many are cosmopolites.

Moreover they are kinds that are well furnished with means of dissemination, and owe to this the circumstance that they have reached the Azores. They seem for the most part to have been

carried by the winds and by birds; and the winds were of secondary importance. The peopling was carried forward rapidly, as the recent origin of the lakes proves. The extreme fecundity of most of the aquatic types and their remarkable faculty of adaptation to cold, heat, and impure waters, and at the same time the freedom from struggle for existence explains why the waters could become so quickly peopled while still decidedly impure from volcanic agency. Further, the study of the aquatic fauna leads to the conclusion that the terrestrial fauna is equally due to the fortuitous introduction of species either from the continents or from the nearer archipelagos or islands of the Atlantic. The fact of greater differentiations in the terrestrial fauna than in the aquatic, and especially in the mollusks (of which the species of *Bulimus* are examples), is a consequence of the much less frequent transportation of the types constituting it and of its more ancient origin. Among amphipod crustaceans the *Orchestia Chevreuxi*, reported as new, is probably a modified marine form. At a former epoch, when the oceanic currents or conditions were different from now, various species have been brought to the archipelago on floating bodies and even upon ice. The presence of erratic blocks on the shores of Terceira and Santa Maria sustains this conclusion.

The alpine character often attributed to the fauna M. Guerne does not regard as established. The species so considered are those of very wide distribution. The present fauna will probably be soon more or less displaced by new introductions.

III. Miscellaneous Scientific Intelligence.

1. *Meeting of the American Association for the Advancement of Science, for* 1888.—The date of August 22d, for the meeting of the Association at Cleveland, has been changed by the Local Committee to the 15th, on account of another great gathering to take place there that week. The special office and reception rooms of the Association will be at No. 407 Superior street, next door to the Hollenden, where will be the hotel headquarters. The meetings will be held at the Central High School Building on Wilson Avenue, where will be the offices of the Local Committee and of the Permanent Secretary during the week of the meeting.

2. *Annual Report of the Board of Regents of the Smithsonian Institution*, showing the operations, expenditures and condition of the Institution to July, 1885. Part II.—This volume of 940 pages is occupied, after reports of progress in the several departments, with an illustrated descriptive report by Thomas Donaldson, of the George Catlin Indian Gallery, in the U. S. National Museum, with a memoir and statistics. It is illustrated by nearly 150 plates and maps, which have wide ethnographic, historical and geographic value.

3. *Lick Observatory, University of California.* — The Lick

Observatory was formally transferred by the Lick Trustees to the Regents of the University of California on the first of June. The expenditures leave about 90,000 dollars of the fund for the expenses of care and use—a small sum which the University hopes to see raised by further beneficence from the wealth of the State to a million. The address of the officers of the Observatory is "Lick Observatory, Mt. Hamilton, via San José, California." The officers connected with the observatory are: Edward S. Holden, director and astronomer, S. W. Burnham, J. M. Schæberle, J. E. Keeler and E. E. Barnard, astronomers, and C. B. Hill, assistant astronomer, secretary and librarian.

4. *A matter of interest to Societies, Libraries and Geologists.*—Any institution or individual desiring to obtain the publications which will be distributed to the members of the approaching Geological Congress in London, as well as the published volume of its Proceedings, may accomplish this by sending ten shillings (about $2.50) to "William Topley, Esq., Gen. Secretary of the Committee on organization of the London Geological Congress, Museum, 28 Jermyn St., London," stating the name of the sender and the object of the sum enclosed. Some of the publications thus obtained will have great value and cannot be otherwise preserved. Each of the two volumes of the Proceedings of previous sessions of this Congress which have yet been published (those of Paris and Bologna) are difficult to procure and cost much more than the sum above mentioned. P. F.

5. The next session of the *International Geological Congress* (the 4th) will open on the 17th of September. All persons desiring to become members are requested to address the secretary at an early date, mentioning their names in full, places of residence, and positions or titles. The fee is ten shillings. Members who have paid the fee will be entitled to the Proceedings and other ordinary publications of the Congress, whether present at the meeting or not. Professor Prestwich is president of the meeting.

6. *Hayden Memorial Geological Fund.*—Mrs. Emma W. Hayden has given to the Academy of Natural Sciences of Philadelphia in trust the sum of $2,500, to be known as the Hayden Memorial Geological Fund in commemoration of her husband, the late Prof. Ferdinand V. Hayden, LL.D. According to the terms of the trust a bronze medal and the balance of the interest arising from the fund are to be awarded annually for the best publication, exploration, discovery or research in the science of geology, and paleontology, or in such particular branches thereof as may be designated. The award and all matters connected therewith are to be determined by a committee to be selected in an appropriate manner by the Academy. The recognition is not to be confined to American naturalists.

Academy of Natural Sciences of Philadelphia, May 10, 1888.

7. *Medals of the Geological Society of London.*—At the anniversary meeting of this Society in February last, the Wollaston gold medal was awarded to Mr. H. B. Medlicott; the Murchison

medal to Professor J. S. Newberry; the Lyell medal to Professor H. Alleyne Nicholson.

Obituary.

Roland Duer Irving.—Prof. Irving of the University of Wisconsin, died suddenly of paralysis at Madison, Wisconsin, on the 30th of May. Mr. Irving had won for himself the reputation of one of the world's best geologists by his elaborate memoirs as geologist of Wisconsin, and also of the United States Geological Survey, on the Archæan and Copper-bearing rocks of Wisconsin and the adjoining regions about Lake Superior, and much was expected of him in the continuation of his labors. He was born in New York on the 27th of April, 1847, and therefore had passed but a few days beyond his forty-first birthday. He graduated in 1869 at the Columbia College School of Mines as a Mining Engineer, and ten years later the Institution conferred on him the title of Doctor of Philosophy. In 1870 he entered on his duties as Professor of Geology, Mining and Metallurgy in the University of Wisconsin, a position which he held until his death. From 1880 to 1882 he was one of the United States Census Experts.

The new geological survey of Wisconsin, authorized by the State in 1873, included Prof. Irving among its geologists. He had previously begun his study of the rocks, and in February of 1872 published the first of his papers on the subject that appear in this Journal. The results of his further labors in the study of the minerals, rocks and geology of the State occupy a large part of the several volumes of final reports published between 1877 and 1883; and they all bear the marks of careful, conscientious work, by one who was thoroughly prepared for the difficult problems before him. His State work supplemented by additional investigations in 1882, when he was put in charge of the Lake Superior Division of the U. S. Geological Survey, was the basis of his volume on the Copper-bearing rocks of Lake Superior, published by the Survey in 1883, and also of other memoirs on the Archæan rocks which were preliminary to a full report that remains unfinished. He had selected assistants for the present season but a few days before his death. His paper on the Huronian in volume xxxiv (1887) of this Journal is, we believe, his last publication.

Prof. Irving leaves a widow, two sons, and one daughter.

A. H. Worthen, the excellent State Geologist of Illinois, died in the early part of the month of May. A notice is deferred to the following number.

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THE

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[THIRD SERIES.]

ART. XI.—*History of the Changes in the Mt. Loa Craters;* by JAMES D. DANA. Part II, on MOKUAWEOWEO, or the SUMMIT CRATER, continued.

[Continued from page 32.]

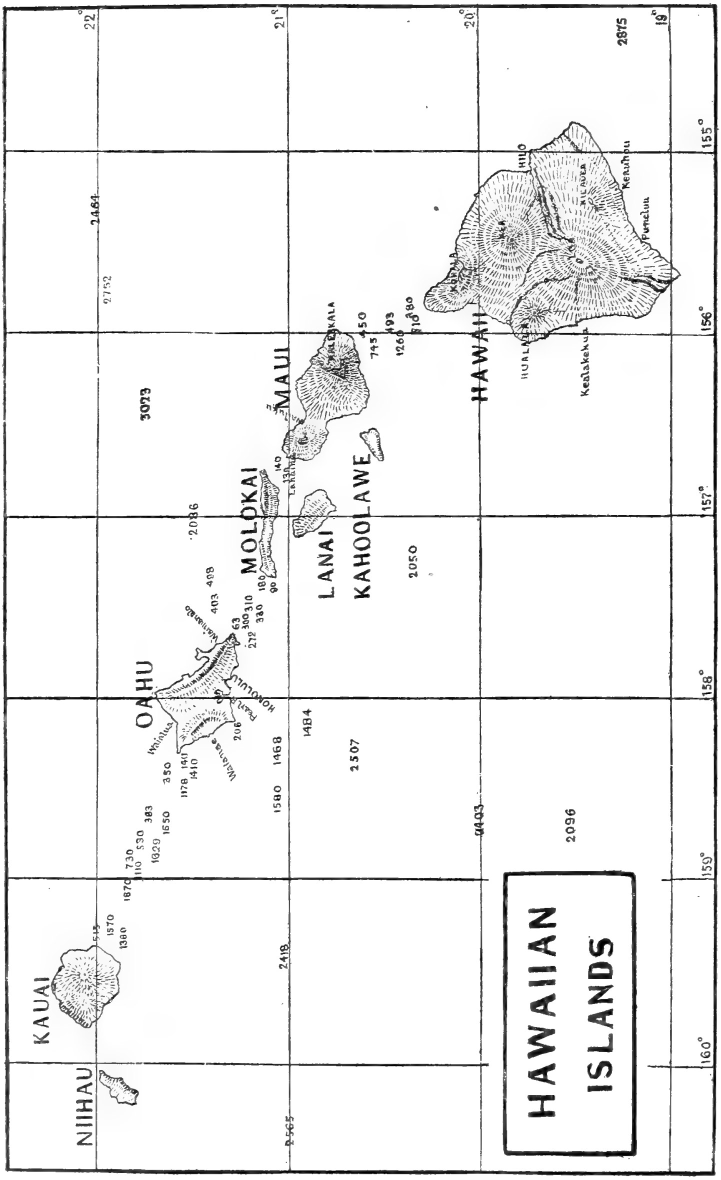
GENERAL SUMMARY WITH CONCLUSIONS.

THE subjects connected with Mount Loa and the summit crater considered in the following summary and conclusions are the following:

1. *The times and time-intervals of eruptions and of summit illuminations or activity,* with reference to (1) periodicity, (2) relations to seasons, (3) variations in activity since 1843, and (4), the changes in the depth of the crater.
2. *The ordinary activity within the summit crater.*
3. *Causes of the ordinary movements within the crater.*

Next follows Part III, treating of the causes of eruptions in Mt. Loa and Kilauea, and afterward, of the relations of the two volcanoes.

For the further illustration of the volcanoes the following map of the Hawaiian Islands is here introduced. Besides showing the forms of the islands, their relative positions and the two parallel lines between Oahu and Hawaii, it gives also the depths from the soundings of the Challenger and of vessels of the U. S. Navy, and others made with reference to telegraph-lines between the islands for which the map is indebted to the Hawaiian Government Survey.


HAWAIIAN ISLANDS
NIIHAU
KAUAI
OAHU
HONOLULU
MOLOKAI
LANAI
KAHOOLAWE
MAUI
HAWAII
HILO
KILAUEA
Kealakekua

1. *Times and Time-intervals of Eruptions.*

1. *Question of Periodicity.*—Commencing with the eruption of 1832, there have been nine registered eruptions of Mt. Loa. Their times and heights of outflow, directions and lengths of stream, and relations to earthquakes, are stated in the following table:

	Reported Earthquakes.	Height of chief out-flow.	Direction and length of flow.
1. 1832: June 20, 2-3 weeks,	none.	Summit.	No outflow.
2. 1843: Jan. 9 to end Feb., 1½ mos.	none.	11,000.	N.N.W., 15 m.
3. 1851: Aug. 8, for 3 or 4 days,	none.	12,900.	W., 10 m.
4. 1852: Feb. 17 into March, 20 d'ys	none.	little over 10,000	E., 20 m.
5. 1855: Aug. 11 to Nov., '56, 15 ms	none.	12,000.	E., 26 m.
6. 1859: Jan. 23 to Nov. 25, 10 mos.	none.	10,500.	N.W., 33 m.
7. 1868: March 27, 16 days,	earthquakes	3,000.	S., 10–11 m.
8. 1880: Nov. 5 to Aug., '81, 9 mos.	none.	11,100.	E., 30 m.
9. 1887: Jan. 18, 10 days,	earthquakes	5,600.	S. 14 m.

The intervals between these eruptions, reckoning (A) between their beginnings, and (B) between the end of each and the beginning of the following one, are:

	A.	B.
Between eruptions—1 and 2	10 years 8 mos.	10 years 7 mos.
2 and 3	8 " 7 "	8 " 5½ "
3 and 4	6⅓ "	6 "
4 and 5	3 " 6 "	3 " 5 "
5 and 6	3 " 5 "	2 " 2 "
6 and 7	9 " 2 "	8 " 4 "
7 and 8	12 " 7 "	12 " 7 "
8 and 9	6 " 2½ "	5 " 6 "

The eruptions above enumerated, that of 1832 perhaps excepted, were great eruptions; that is they had outside or subaerial outflows. But the history shows that at other times in the sixty-five years the summit of the mountain has been often brilliantly lighted, and surmounted with a column of clouds of great height, made apparently from the escaping vapors, which became a lofty column of light at night. These summit illuminations have been shown to be evidence (p. 27) not merely of action in or about the crater, but decisively of a boiling or fountain-like activity in the liquid lavas, if not also of out-flowing streams. The drifting of Pélé's hair on such occasions 35 miles to Hilo is as good testimony to the playing of jets or fountains as a note from an observer at the summit.

Moreover, we have learned from Kilauea that these times of brilliant action within the crater may be followed by subterranean or submarine discharges when not by subaerial; and therefore that they are not always merely the flaring up and

fading out of the crater-fires. They announce that *the top of the Mt. Loa column of liquid lavas is in the crater*, or has its maximum length, and is at serious work, even if no outbreak ensues.

The following table contains the times of these minor displays, as well as those of the admitted greater eruptions. In the table the latter are indicated by italics:

Dates.	Conditions at the Summit.
1. 1832. June 20.	Bright light at the summit, 2–3 weeks.
2. 1843. *Jan.* 9 *to late in Feb.; 1½ mos.*	Clouds; Jan. 10–17, bright light.
3. 1849. May, 2 to 3 weeks.	Brilliant light; just after activity in K.
4. 1851. *Aug.* 8; *3 or 4 days.*	Bright light for 3 or 4 days.
5. 1852. *Feb.* 15 *to June; about* 4 *mos.*	Brilliant light for 24 hours.
6. 1855. *Aug.* 11 *to Nov.*, 1856; 15 *mos.*	Bright light at beginning.
7. 1859. *Jan.* 23 *to Nov.* 25; 10 *mos.*	Brilliant light at first.
8. 1865. Dec. 30; 4 mos.	Brilliant light for 4 mos., varying; at close, Kilauea increases its activity.
9. 1868. *Mar.* 27 *to Apr.* 12; *the flow 4 days.*	Bright light from March 27 to 30.
10. 1872. Aug. 10, into September.	Brilliant; a lava fountain of 500 feet; a tidal wave on the coast; K. very active.
11. 1873. Jan. 6, 7; 2 days.	Brilliant.
12. 1873. Apr. 20 to Oct., 1874; 18 mos.	Brilliant more or less for 18 mos.; in June and Aug., '73, a lava fountain, 300–600 feet.
13. 1875. Aug. 11; one week.	Brilliant.
14. 1876. Feb. 13; few days.	Brilliant.
15. 1877. Feb. 14; few days.	Brilliant; a submarine eruption.
16. 1880. May 1.	Brilliant: a lava fountain of 900 feet; Pélé's hair fell in Hilo.
17. 1880. *Nov.* 5 *to Aug.*, 1881; 9 *mos.*	Bright for a few days.
18. 1887. *Jan.* 16; *ten days.*	Bright for a few hours.
19. 1887. Nov. 25, into Feb.; 1 mth.	Vapors; no light seen.

The table contains the dates of ten periods of summit activity or illumination independent of the great eruptions; some short, but others prolonged for months, and varying greatly from time to time in brightness.

All these minor displays have taken place without initiating or announcing earthquakes.

It is obvious from the tables that the lengths of the intervals between the eruptions and the summit illuminations are too various, as far as now understood, to sustain the idea of periodicity.

2. *Relation to seasons.*—The evidence of a seasonal relation appears to be beyond question. Out of the whole number. 19, 5, counting in that of 1865, occurred in January, 3 in February, 4 in March, April and May, and 1 in June, making 13 in the first six months of the year. Of the remainder, 4 commenced in August and 2 in November. Thus 15 out of the 19 took place in the wetter season. Add to these facts those from Kilauea mentioned in volume xxxv, p. 16, where the months given are March ?, January or June, May, May, Octo-

ber, April, April, March, and the number for the same months of the year becomes 20 or 21 out of 27.*

Full meteorological tables for a comparison of the months as to precipitation, both at the base and summit of the mountain, do not exist, and the discussion of this important question has, therefore, to be left unfinished.

I have received the following notes on the snows of Mt. Loa in a recent letter from Mr. J. S Emerson of the Hawaiian Government Survey. "The snow-cap of Mt. Loa in general may be considered as making its first appearance in the early part of November, and as lasting until late into March. This is my impression from observations the past season, which I think has not been particularly exceptional. During the early part of November the snow-fall was quite light, and seemed to melt rapidly away at its lower edges. By the 25th there had been two heavy snow-storms covering the mountain top with a thick coat, which lasted all through the winter. The snows are usually the heaviest in the month of February, I think, though I did not see the mountain during that month this year. My last view of Mt. Loa was on March 29th, when I could just distinguish patches or streaks of snow on the more protected portions of the summit."

The *relation to barometric changes* is an important subject for future study, with respect to which we have now no knowledge. There are also variations in the amount of vapors over the active craters dependent on *hygrometric changes* to be investigated.

In view of the above facts it is probable that if there is any periodicity in eruptions, it is more or less dependent on meteorological cycles.

3. *Variations in activity since* 1843.—The copiousness of the subaerial discharges has diminished greatly since 1859. Before the end of that year, or in the 17 years from 1843 to 1860, five of the eight great eruptions had occurred; and of the three in the following 27 years, only one, that of 1880–81, was of great length.

The frequent occurrence of the brilliant summit displays during the twelve years preceding the middle of 1880 is another striking fact. Six cases are reported, and one was prolonged with small interruptions for eighteen months.

The first of these displays occurred nearly 4½ years after the eruption of 1868. But Mr. Coan, the mountain chronicler, was absent in this country during one year in the interval—from the spring of 1870 to that of 1871. After the summit-display of August, 1872, they came at short intervals, their

* This relation to the seasons, first recognized by Mr. Coan, is mentioned also by Mr. Green in his Vestiges etc., p. 332.

lengths from the end of one year to the beginning of another, reckoned in months, being 5, 3, 10, 6, 12. After February of 1877, there was the longer interval of $3\frac{1}{3}$ years. Such short-period alternations seem to imply the recurrence after each of a subterranean discharge somewhere, if not a subaerial. The display of 1877 quite certainly ended in a submarine eruption, and probably that of 1872, (pp. 29, 26).

4. *The changes in depth of the summit-crater.*—The changes since the year 1834, when the crater was visited by Douglas, have diminished its depth by at least 400 feet, if we may trust—as we probably ought to do—his measurement "with a line and plummet," making it 1,270 feet. In 1840, Lieut. Eld, U. S. N., of the Wilkes Exploring Expedition, made the depth on the west side 784 feet (p. 16), and in 1885, J. M. Alexander, 800 feet, (plate II).

We know nothing as to variations in the level of the floor after and before an eruption, and nothing as to the down-plunges which have followed discharges. The terrace-levels situated at the north and south ends of the crater may mark high lava-levels just previous to some ancient eruption; but they antedate history; for Wilkes's map (p. 17) shows that they existed in 1840 very much as now. The map, Plate 2, by J. M. Alexander, which contains his "estimates" of the depths of the terraces or "plateaus" below the highest point or summit, makes the terrace at the south end on a level with the upper of the two at the north end, suggesting thus that the two may mark one of the high-lava levels of the crater. In addition, it places the bottom of the South Crater (D), and that of the pit in the upper north terrace or plateau (A′), at or below the level of the bottom of the central crater, favoring the view that all three parts of Mokuaweoweo are still in active connection; which view is sustained by the facts (1) that the fountain of May, 1880, was a South Crater fountain, and (2) that the pit A′ was formed since 1874, as it is not in Lydgate's map of the crater of that year.

2. *The Ordinary activity of the Mt. Loa crater.*

1. *General course of action.*—Although but few ascents to the summit-crater have been made since the first by Douglas in 1834, and only four of these found the crater in action, there are still facts enough for important conclusions. The *cycle of changes* has been, beyond doubt, the same essentially as in Kilauea; that is, when a discharge takes place: (1) the lava of the lava-column within the central conduit of the mountain falls to a level some distance below the crater (say one or more hundred feet), as a consequence of the loss by the out-

flow. Then begins (2) a rising of the lava of the column until it again shows part of its fiery top in the bottom of the crater engaged in its usual projectile work, and until finally it has reached a maximum height; and then follows (3) a new discharge, and another time of inactivity for the crater.

2. *The projectile action within the crater.*—Projectile action in the Mt. Loa crater is in strong contrast with that of Kilauea. Instead of the Kilauea feature of low jets suggesting ordinary ebullition, with only occasional throws to a height of 100 to 200 feet, the descriptions of the summit action tell solely of fountains of clustered jets 75 to 600 feet, and even 900 feet high, as if the height of the jets or the intensity of the action was proportional to the height of the lava-column. The four accounts of this activity, one in 1872, two in 1873, and one in 1880, are alike in this respect. One of the two in 1873 describes the crater when the summit-light appeared feeble from below, and the other when brilliant, and the former is scarcely less marvellous in its fountains. The evidence is almost conclusive that such fountains are of ordinary occurrence. This was the opinion of Mr. Coan; and Mr. W. L. Green, in view of his summit observations in 1873 (p. 28) and the reported facts of others, ascribes to all the periods of summit illumination "great fountains."

3. *Causes of the Ordinary movements within the Crater.*

1. *The rise of the lava in the conduit.*—The rise of the conduit lava may be safely attributed in part, probably a large part, as in Kilauea, to the quietly-acting ascensive force in the lava-column.

The other volcanic agency of greatest prominence, as admitted for other volcanoes, is that of the *rising*, *expanding* and *escaping* vapors. The vesiculating effects of the vapors as regards the Mt. Loa flow of 1880–81 have been already described (xxxv, 222): and it remains to consider—

2. *The cause of the high projectile action in the summit crater.*—Higher projectile action in Mt. Loa than in Kilauea through the escape of elastic vapors might come (1) from greater viscidity in the lava; or (2) from less specific gravity of the material; or (3) from a larger supply of vapors. The first of these causes cannot be the right one, for greater viscidity should lead to high cinder ejections; on the contrary, the lavas show that they are as mobile as the Kilauea lavas by the velocity of the lava streams and all the attending phenomena, and more by the free play of the fountains. The second is set aside by the near identity of the lavas in density:

that of the Mt. Loa flow of 1880–81 being 2·98; that of ordinary Kilauea lava, 2·97–3·05; an old lava, from Waldron's ledge, excessively chrysolitic, 3·15.

If neither of these explanations meets the case, we have only the third to appeal to—a greater volume of elastic vapors. It is, accordingly, probable that the cause which can produce *occasional* jets of 100 to 200 feet in Kilauea is capable of producing the *prevailing* high jets or fountains of the summit of Mt. Loa.

But why should the volume of vapors in the lava-column be greatest at the summit? The amount of work done there is ordinarily at least 100 to 1000 times greater than in Kilauea; for the jets are 5 to 10 times higher.

This difference in amount could not be a fact if the vapors within the slowly ascending lavas were from the profound depths that supply the lava, or even from depths much below the sea-level. For, under such circumstances, (1) the difference in the amounts carried up to the two craters would be small, since the rate of supply from below would be essentially uniform; and (2) the difference in the height of the columns would be more favorable to Kilauea, whose lava-column rises above tide level but 3700 feet, than to Mt. Loa 9000 feet higher. The area of the floor of Kilauea exceeds that of Mt. Loa.

But if freshwater from precipitation over the island supplies the vapors, then the difference in the heights of the conduit lava-columns is greatly in Mt. Loa's favor. A section of its lava column at the sea-level may receive moisture during the whole time of its rise to the summit, a distance 3·8 times that for Kilauea. The ratio 3·8 to 1 for the difference in supply of moisture to the columns would be too large on account of the less precipitation over the upper part of the mountain and the much less extent of surface in this part; but it may safely be put at 2 to 1, if not 2½ to 1. The ascensive movement in the Mt. Loa lava-column may be somewhat more rapid than in the shorter conduit of Kilauea, provided the hotter central portion derives any upward thrust from the pressure of the cooler lateral portion, (xxxiv, . . .); and this cause would diminish the difference between the two as to the supply of vapor received; yet not largely.

The fact here apparently established—that only through waters from the island-precipitation could Mt. Loa get its larger supply—affords new evidence that *the inland waters are the chief source of the vapors concerned in Hawaiian volcanic action.*

Is there any other source of the Projectile action? The lava-fountains of the summit-crater are so marvelous in size considering the density of the lavas, so near the incredible, that we naturally seek for other possible explanations.

Hydrostatic pressure is out of consideration, inasmuch as the fountains are at the summit of the dome and at times throw their jets 50 to 100 feet above the mountain's top—over 14,000 feet above the sea-level.

Another source of projectile action has been suggested by Mr. Green, as briefly mentioned on a preceding page (xxxv, 216). In opposition to other writers on volcanoes, he sets aside the idea that vapor of water is concerned effectually in the projectile action even of Kilauea. The feeble amount of vapors observed by him over the fountain of the summit-crater in 1873, and the general absence of vapors from the flowing lava-streams of 1859 and 1880–81, besides other similar facts, have led him to his position on this point. He recognizes the fact* that great heaps and columns of clouds form over an active crater, and rise at times to a height of many thousands of feet; but accounts for these on the assumption that the heated current ascending from the active crater derives rapid accessions of air from either side, and this air, by being carried up to cold heights, yields the moisture by condensation, and so forms the column of clouds. Further, he finds a cause of some projectile action for the Kilauea lava-lakes and others in atmospheric air carried down by the descending lavas of the jets into the lava-lakes—as the crests of waves carry down air into the sea; and for the rest of it, or that producing the crater-fountains like those of Mt. Loa, he holds that the ascensive action in the conduit, after a time of quiet, suddenly overcomes resistances or stoppages that have come to exist in the conduit at depths below, and, as a consequence, the lavas, suddenly released, are thrown up in fountains, like the jets of mineral oil from an artesian boring.

I have already met part of the argument as to the absence of vapors of water, in my remarks on vesiculation, by showing (1) how extremely little moisture is needed to produce vesiculation (xxxv, 226), and (2) how much moisture hot air will dissolve and make invisible. It has also been stated (3) that if a Mt. Loa lava-stream has but a single fountain-head, as is generally supposed, though not proved, nearly all the vesiculation must occur at the source, so that for this reason and the heated air above it, the lava-stream should be vaporless, or appear so, except where there are fissures below for additional supply.†

Further (4), direct observation proves that the vapors come up out of the crater. They often rise directly from the

* Vestiges of the Molten Globe, pp. 75, 162–167, 175, 272–278, 309, 314.

† Mr. Green states, as an exceptional case, that at one place on the Mt. Loa flow of 1880–81, the lavas spread into a large lake, and vapors rose from it in great amount. This is good evidence of the existence there of a local supply of lavas through a fissure.

orifice of the crater, too low down for the air-current to have got into action; and in such cases there is an obvious source for the condensed moisture, and that is, the liquid lavas of the crater. Mr. Green expresses the fact well in the words (p. 169) "There is very often a large quantity of smoke seen to arise from the orifices of eruption, and this often spreads out in the higher regions of the atmosphere. There was a column, perhaps 500 feet wide and 10,000 high, arising from the orifice of 1859 when we pitched our tent along side it," at a point on the mountain 10,500 feet above the sea-level.

Further (5), the feeble amount of vapor observed by him in 1873 over the fountain in the summit-crater, so unlike what had existed a few days before, may have its explanation in the dryness of the atmosphere at the time. The air is generally dry at the summit, but must have its phases of unusual dryness, during which an unusual amount of escaping moisture would, for this reason, become invisible.

(7) The summit fountain is a combination of jets, each of which must have had its initiating projectile act; and it continues for weeks and months; and this is at variance with the evidence from Kilauea, which makes the ascensive action very gradually and quietly lifting, instead of projectile.

Finally (8) the cold atmospheric air carried down into a lava-lake by the jets could generate very little projectile power. The air, on entering the lavas, would encounter a temperature near 2000° F. if not beyond it, and hence the expansion would cause expulsion, or a speedy escape, in spite of any currents or intestine movements that might exist in the boiling cauldron.

For these reasons we may conclude that the old and generally accepted explanation which attributes the projectile action chiefly to water-vapor is not seriously invalidated by the ingenious suggestions brought forward by Mr. Green.

Part III.—ERUPTIONS OF KILAUEA AND MT. LOA.

In the following pages the subjects considered are: I. The characteristics and causes of eruptions; II. Metamorphism under volcanic action; III. The form of Mt. Loa as a result of its eruptions; IV. The relations of Kilauea to Mt. Loa; V. General volcanic phenomena.

Under the head of Eruptions, the principal topics are: the kinds; the places of outbreak; the causes of eruptions; the characters of the lava streams; the positions and origin of the subordinate lateral cones.

I. Characteristics and Causes of Eruptions.

Eruptions are of two kinds: (1) *Non-explosive eruptions*, or quiet outflows, seismically attended or not; and (2) *Explosive eruptions*, or catastrophic upthrows. Both kinds are exemplified in Hawaiian volcanic history. There are also (3) combinations of the two kinds in volcanic regions.

1. ORDINARY OR NON-EXPLOSIVE ERUPTIONS.

Kilauea and Mt. Loa are alike, as has been shown, in (1) their mode of work; (2) the southward position, in the crater, of the point of greatest activity; and (3) the general features of their eruptions. But in amount of eruptive work the summit crater is far ahead of Kilauea, and, in fact, it leads the world. Kilauea has had but one subaerial outflow of any magnitude in the last fifty years, and that only twelve miles long. Mt. Loa, on the contrary, although nearly 13,000 feet up to the bottom of the crater, has had in the same time only one of its eight less than twelve miles long, and several between twenty and thirty-five; and it has reached its height without a loss of eruptive power. It is reasonable, therefore, that Mt. Loa should have most instruction to give about outflows.

1. *Heights and positions of the places of outbreak.*

1. *The Heights.*—The place of outbreak of a Mt. Loa eruption may have any height from the summit to levels far below the sea-level; and this "far below" may be, as the map on p. 82 shows, 17,250 feet down before reaching the actual foot of the eastern slope. The heights of known occurrence are mentioned in the table on p. 83. The completion of the topographical survey of Hawaii, now in progress under the government, will before long give more correct figures. The height of the source of the one Kilauea outflow, that of 1840, or rather of the spot where it appears to begin, is 1244 feet (Wilkes).

In each of the cases of eruption, fractures were made near the summit which extended down the mountain, with only small discharges along them when any, to the place of chief outflow. In some cases, fissures have opened on the brink of the crater and let out lavas; but all the large outflows of modern time have come from points a thousand feet or more below the summit.

2. *Relations between the positions of the places of outbreak and the diameters of the craters.*—The course of the northern half of the longer diameter of the summit crater is about N. 35° E., and that of the southern half, about N. 20° E. or

S. 20° W., as marked on the upper and lower margin of Plate II. Four of the largest lava-streams of Mt. Loa, those of 1843, 1852, 1855 and 1880, and two others to the south, those of 1868 and 1887, have their places of outbreak nearly in the line of the respective halves of *the longer diameter.* Again, three of the eruptions, those of 1851, 1859 and 1877, broke out on the west side of the summit, nearly in the line of *the shorter diameter*, or between the summit and Hualalai.

There is here probable evidence of a dependence of the eruptions to some extent on the two great fissure-lines upon or about which the mountain's foundations were laid.

The direction of the longer diameter of Kilauea is about N. 50° E.–S. 50° W. The chief course of eruptions, as on Mt. Loa, is marked by a line of fissures and ejections running west-southwestward in the direction of the longer diameter. But the large outflow of 1840, and the fissures leading to it, instead of pointing toward the crater, have a course nearly *parallel* to the longer diameter, but fifteen miles south of the Kilauea line. This is seen on the map, page 82, but better on Plate I, the stream being the one near the east cape.

2. *Causes of Eruptions.*

1. *State of readiness for an Eruption.*—The *ordinary quiet* work of the craters has been shown to be carried on by—

(1) The ascensive force of the conduit lavas; this force producing (1) a slow rise in the liquid rock from depths below; and (2) a raising of the crater's bottom.

(2) The elastic force of rising, expanding and escaping vapors; producing jets and fountains in the lava-lakes; overflows or ejections spreading the lavas over the crater's bottom; vesiculation of the lava and consequent increase of its bulk.

Other causes have been mentioned as occasionally in action (xxxv, 228), but as not essential to the chief results.

After a season of this ordinary activity, with more or less gradual increase of intensity, a state of readiness for an eruption and its determining conditions have been reached. This has happened when the lava has risen, through these agencies, to what might be called *high-lava mark;* a level some hundreds of feet above low-lava mark or the low level occasioned by the preceding discharge.

2. *Action needed for an Eruption.*—After this preparation nothing is needed for an eruption but an agency of sufficient force to break the lava-conduit; for if broken seriously the lava will run out, and therein is an eruption or discharge.

Neither of the agencies carrying on the ordinary quiet work of the volcano has shown itself capable, during historic time, that is, since 1822, of breaking the lava-conduit for a discharge.

The escaping vapors have spent their force mostly in making jets and fountains and feeble outflows; and still more quiet has been the work of the ascensive force. Eruptions have been a sequel to years of this quiet work, but not a direct effect of the action.

3. *Agency of Earthquakes.*—Earthquakes have often been considered an effective agent in eruptions. But during the past sixty-five years only two of the eruptions of Mt. Loa and one of Kilauea have been introduced or attended by noticeable earthquakes. The eruptive agent in both volcanoes has in general worked quietly, "as quietly as the moon rises," says one writer, without much exaggeration. The star-like light on Mt. Loa has been followed soon by a stronger glow; and, accompanying this, a rising of clouds into heaps and lofty columns. After a day or two or three, the summit-light having disappeared, the flow has begun one, two, or three thousand feet below the top; and a line of light has then slowly lengthened down the mountain for twenty or thirty miles; and all this, quietly. It is the grandest of volcanic work with the least possible display of force.

The facts connected with the two eruptions of Mt. Loa and one of Kilauea, that were attended by earthquakes, merit special review in this place because they teach what earthquakes may do, and by what means. The three occurred in the years 1868 and 1887.

On a Friday in 1868, March 27 (p. 24 and xxxiv, 91), a light was seen on the mountain and feeble earthshocks occurred. Only slight eruptions followed. Then, in accordance with the ordinary rule, these first fires at the summit disappeared. But the earthquakes increased in violence—not about the summit, but far to the southward, within the lower three or four thousand feet of the mountain. And they continued increasing until that "terrible shock" of Thursday, April 2d. Five days later, April 7th, the lava burst out from an opened fissure at a point, 23 *miles distant from the summit* and only 10 or 11 from the sea-coast.

It is here manifest that the earthquakes had nothing to do with *preparing* for the eruption; they were too late for this. It is possible that the first break near the summit anticipated the first earthshock But below, in the region of most violent disturbance, greater fissures were opened, the profoundest probably at the very time of that "terrible shock;" and as soon after as the subterranean passage could be made—about five days—the lava from the broken lava-conduit or reservoir made its appearance at the surface and hurried down the mountain to the sea. But at the sea-border and elsewhere the fissures were probably ahead of the lava, according to Professor

C. H. Hitchcock, and gave it exit nearly all the way, occasioning their rapid progress seaward.

Here then it is clear what the earthquakes did to produce the eruption. They, or the cause generating them, broke a hole into the conduit, and the lava escaped. The lava of the conduit was not thrown into commotion or projected to great altitudes at the summit; instead, it sank out of sight, following the rent to the surface far down the mountain. These events were repeated almost precisely in the Mt. Loa eruption of 1887. The locus of the outflow and of the earthquakes in both cases was far south in southern Hawaii, and the two streams followed near and parallel lines; the chief difference between them was in the higher outlet in 1887 by 2500 or 3000 feet (see map, page 82).

The earthquake eruption of Kilauea was coincident with the first of the two Mt. Loa eruptions in April, 1868. The earthquakes were the same identical earthquakes; and that "terrible shock" of April 2d was for each the special discharging agent. Immediately after the shock the fires of Kilauea, before unusually active,* commenced to decline; by night of that Thursday, all the burning cones, by night of Saturday all the smaller lava-lakes, and by Sunday night, the great South Lake, had become extinct. And then, the lavas having run off, half the floor of the crater sunk down 300 feet.

A genetic connection between the earthquake disturbance and the eruption cannot be doubted. The earthquakes came after the crater had reached a state of unusual activity, and hence could have taken no part in the preparation. They simply discharged the lava by breaking the conduit that held it.

Moreover, the earthquakes which thus emptied Kilauea were of Mt. Loa origin; they had their center thirty miles or more west of Kilauea, and were made through the Mt. Loa fires. It is a case, therefore, of one mountain-volcano accidentally discharging the conduit-lava of another. The work was simply a fracturing of the mountain in different directions; for the island was violently shaken from the west side to Hilo on the east coast; and, in the general fracturing, the two volcanic conduits were broken at once, an accident not likely to often happen.

It is also to be noted that *the earthquakes were of local or volcanic origin.* This is established by the fact that only two of the heaviest shocks reached westward to Honolulu on Oahu

* Dr. Hillebrand states that for two months previous to the eruption there were eight lava-lakes in the bottom; and until March 17th, a very active blow-hole in the northwest corner, where "large masses of vapor were thrown off as from a steam engine" on Thursday, April 2d, after the earthquake, there were fearful detonations in the crater, and portions of the wall tumbled in; and then began the decline.

(p. 24); and these so feebly that they did not make themselves generally felt in that city (see map, p. 82). The depth of the oceanic depression between Hawaii and Oahu, which is only 500 fathoms where least (between Hawaii and Maui), was sufficient to stop off the vibrations. Further as in the Mt. Loa eruptions, no increase of projectile action was occasioned in the crater by the earthquake disturbance; the lavas simply, in the quietest way, ran off, leaving the crater empty, still and dark.

A mountain having within it two great regions of liquid lava thousands of feet in height, each at a temperature above 2000° F., and with subterranean waters abundant, at least through the lower two-thirds of the altitude, is well fitted for the production of eruptive crises; and it is remarkable that the eruptions of 1868 and 1887 are the only ones seismically occasioned, or attended, in the past 65 years; and, further, that in these eruptions, although among the most violent on record, the craters were wholly free from explosive action.

The violent earthquakes of 1868 and 1887 accomplished nothing so far as the eruptions were concerned that is not effected on Hawaii in four eruptions out of five without them. The greatest of the eruptions have had no such aid. In the preparation for a discharge, the mountain has reached a dangerous state, because of the elongation upward of the fire column; then the fracturing agency has done its work; earthquakes are only a possible incident. With or without them, the conditions and results are the same; for vibrations necessarily attend fracturing, and earthquakes are simply the stronger or perceptible earthshocks.

4. *The rupturing and ejecting forces.*—The chief cause of the rupturing is no doubt the elastic force of suddenly generated vapor. So far this is an accepted explanation. As to the conditions under which this vapor is generated, there is not so general agreement.

The facts show, *first*, that on Hawaii the vapors are not suddenly generated *within* the conduit; for in the event, the lavas slink away from the crater, instead of dashing up wildly to great heights. If not generated *within*, it must be *without*, and the most probable region is that of the hot exterior of the conduit, or the hot rocks encasing the liquid column, or else fissures or local fire-places adjoining it. In this view the fracturing depends on the sudden access of subterranean waters to this outside region of great heat.

Secondly, the evidence proves that the force makes a fissure or fissures for the discharge of the lava without giving the waters entrance into the conduit. The pressure of the elastic vapor expends itself in breaking the sides of the mountain, and

only under the most extraordinary circumstances is the water forced into the lava-column. The earthquakes of 1868 were an exhibition of the power generated; and hardly less so is the noiseless fracturing for the greatest of eruptions.

Some erupting action comes from hydrostatic pressure. But the fact that the fissures first open quite near the summit of Mt. Loa is evidence that pressure from this source is the least efficient agent.

Why southwestern Hawaii should be especially liable to violent earthshocks in connection with its outflows is not wholly clear. But there are three significant facts bearing on the question.

(1) The southern half of the longer diameter of the Mt. Loa crater, and fissures from it down the mountain, point directly to the place of outbreaks of 1868 and 1887, the probable localities of the earthquake epicentra of those years.

(2) The longer diameter of Kilauea, with a long line of fissures, having the trend S. 52° W., points nearly to the same region of outbreak; so that the *two diametral lines, the Mt. Loa and the Kilauea, there intersect.* (See map, p. 82 and Plate I.)

(3) These lines have long been common directions of fractures and eruptions, as shown by the old lavas of the surface as well as by existing lines of fractures.

This divergence between the courses of the longer diameters of the craters of Mt. Loa and Kilauea comes up again for consideration in the remarks on the relations of the two volcanoes.

In the eruptions the *ejecting* force may be feeble or null; for the lava may flow out, when the source favors it, simply through gravity; but, in general, ejection is pushed forward, (1) by the elastic vapors within the lava-column; by vapors generated outside, like those producing eruptions; and by hydrostatic pressure.

The first of these causes is the source of the high fountains in the summit crater; and the summit effects indicate that it should have great propelling power at places of outflow. The fountains at the outflows have hitherto been attributed to hydrostatic pressure; but the two causes must here act together, and it is impossible to say from present knowledge which preponderates.

Fountains attended the outbreak at the eruptions of 1852, 1859, 1868 and 1887 (pp. 19, 22, 24, 32,); and it is probably that examination at other times would have added one or two to the list. The lengths of the lava-column (A) above the place of outbreak at these eruptions, and (B) the reported heights of the fountains in feet, are as follows:

	1852	1859	1868	1887
A	2500	3000	10,000	7000
B	200–700	300–400	200—; 600?	200? 80.

Owing to the height of the column above the level of the outlet in 1868, 10,000 feet, the hydrostatic pressure should then have been greatest; the force from the vapors in the lava-column, least; and the friction in the very long passage-way from the broken conduit, the most obstructing.

The second source of ejecting and fracturing pressure mentioned above is the probable origin of the fractures which sometimes cut through the walls of a crater to the summit; and if the vapors producing the pressure are generated over a source of liquid lava, the fissures would necessarily become injected with lava which might flow out above in a stream. Cases of this kind about Kilauea occurred at the eruptions of 1832 and 1868, (xxxiii, 445, xxxiv, 92); and Mr. W. T. Brigham and Rev. J. M. Alexander mention others, of uncertain date, about the summit crater.

Mr. Alexander speaks of a "cataract of lava" descending the walls into the crater from the summit; and farther south, of two other similar cataracts; and at the summit he found the deep fissure from which the cataracts had been supplied with lava, and ascertained that it had also poured out an immense stream northward upon the first plateau and thence southward into the central crater. "On the southwest side of the crater there had been another eruption from fissures that were still smoking, and the eruption had sent a great stream southward toward Kahuku and had also poured cataracts into the south crater from all sides." "The flows were from some of the highest parts of the brim;" and "from the brink there had been large flows down the mountains." "These outbreaks from fissures around the rim indicate that the lava has rather poured into the crater than out of it; and also that it has flowed from such fissures in vast streams down the mountain side." These cases perhaps date from the eruption of 1880, the last that preceded Mr. Alexander's investigation of the crater.

Such events if attending an eruption belong to its very beginning before the lava is drawn off from the crater. They may occur at other times; that they do so is not yet certain, except in a small way within Kilauea, about the lava-lakes. (xxxv, 228).

3. *The Outflows and the circumstances attending them.*

1. *The source.*—An outflow of lava may commence as a stream or as a fountain. In either case, the pent-up vapors of the lava-column make their forcible escape with the lava; and a cone

of solidifided lava more or less scoriaceous is usually formed about the vent by the pericentric action. These cones are mentioned in the descriptions of all the outbreaks, not excepting that of 1880, which was visited by Rev. E. P. Baker. Large deposits of cinders, or a light scoria, are sometimes distributed over the adjoining region, and Pélé's hair is also a common product; the former where the lava is thrown up in fountains and partially cools exteriorly as it falls (p. 28), and the latter from the action of either the fountains or the low jets (xxxv, 221).

The summit crater of Mt. Loa, unlike Kilauea, is often left, after an eruption, with one or more cinder-cones on the bottom; the larger of them usually in the southern portion of the crater. They are probably made from the lavas as the heat declines with the first commencing movements of an eruption.

2. *Rate of flow.*—The great flow of 1852, so grand in its fountains and twenty miles long, was finished in twenty days; this gives, for its mean rate of progress, a mile a day. The flow of 1859, thirty-three miles long, occupied only eight days, which corresponds to a rate of four miles a day on a mean slope of 1 foot in 15. The thirty miles to Hilo in the stream of 1880–81 took nine months; and the mean slope was 1 foot in 13 or about 5 degrees.

The general conditions in the flow of a great stream, its obstructions and modes of overcoming them, are well described by Mr. Coan (p. 20). As to actual *rate* of flow, we want more precise facts. It is difficult to reconcile the facts stated on these points; and especially the various velocities attributed to the different portions of a flowing stream, for example: the reported rate in one of the tunnels of "40 miles an hour" with a rate for the front of the flow of "one mile a week." The difficulty is still great if we suppose the 40 to be only 10, and whatever the obstructions along the front. The conditions are those of a discharging faucet, and the flow below is that of the liquid after its escape spreading widely over a rough surface.

The many openings through the crust of a stream into the tunnels which give out vapors, and often have the shape of jagged cones, suggest the possibility that a fissure may exist beneath in these and similar places for the discharge of lava and vapors. But the idea that such fissures generally underlie a lava stream (which I formerly thought probable) is opposed by Mr. Coan; and there are not facts to sustain it except for the Mt. Loa stream of 1868 and the Kilauea for 1840.

The tunnels of a stream, made by a crusting of the surface while the lava continues flowing beneath, have a smooth, somewhat glassy or enamelled interior, with horizontal flutings and mouldings which were made by the moving lava. In a tunnel

of the stream of 1880–81, near Hilo, which I visited under the guidance of Rev. E. P. Baker, one of the lines of mouldings had the form and position along the side of a solid handsomely modeled bench, indicating that the lava had encountered an outside obstacle in a projecting angle of cooled rock. This tunnel had a varying height of 4 to 8 feet and a general width of about 30 feet, but also some branchings and lateral expansions of large extent. The roof was two to six feet thick. The smoothness of the interior is favorable to a high velocity. The small capacity of the one entered near Hilo suggested the following queries: How much of the lava of a stream a mile wide runs in tunnels? Does the little width of the tunnel, and thereby of the supply stream, account for the difference of velocity in the tunnels and at the front? if so, the exit should be as free as that from a faucet, or the arrangements would not work. How many such tunnels exist side by side? Does a single tunnel continue on for 20 or 30 miles as an uninterrupted lava duct? We should infer that for a large stream the system of tunnels would become a very complicated one.

Whatever doubts exist as to rate of flow, there is none as to the extreme liquidity of the Mt. Loa lava, and its equalling if not exceeding that of Kilauea.

3. *The amount of Lava discharged.*—There are no data as regards the breadth or the depth of the streams, for a satisfactory calculation of the amount discharged. The depths might at many points be ascertained from the holes left by burnt trunks of trees. We can now only make a supposition.

The flow of 1852 was 20 miles long. If we suppose the mean depth of the stream to be 20 feet, and the mean width, 5000 feet, the amount of lava it contains would be 10,560,000,000 cubic feet. Supposing the lava-column to have the mean diameter of the central part of the summit crater, 9000 feet, it would contain, down to a depth of 2500 feet, (the place of discharge for that eruption) nearly 160,000,000,000 cubic feet of lava, or fifteen times as much as was discharged. Accordingly, the discharge, if the above figures represent the whole amount, would have drawn off less than 200 feet in depth from the lava conduit; and a rise of 200 feet again would have made the mountain ready for another discharge. The calculation is suggestive, though otherwise of little value. In addition to the other uncertainties we know nothing as to how much of a discharge passes off into subterranean cavities; which may be very large, for the great eruption of Kilauea in 1832 has little to show over the surface of the island.

Whatever the amount of lava or of height that is lost by the lava-column at an eruption, it has taken, as has been shown, but a very short time in several cases, to fill up again for a new dis-

charge. I repeat here that after the eruption of 1852, which produced a stream 20 miles long, had closed, the lofty volcano was ready in only 3½ years for a 26-mile flow, that of 1855; and in 3½ years more, for another still longer, that of 1859, 33 miles in length of stream: which is brisk work for the great old mountain. According to these facts the lava-column had risen, after the eruptions, at the rate of at least 100 feet a year so as to reach again the bottom of the crater and be ready for another discharge.

4. *Kinds of Lava-Streams. Pahoehoe and aa.*—The ordinary smooth-surfaced lava-stream, the pahoehoe, needs here no further description. The *aa*-stream is less often seen in process of formation and is more difficult to understand. With reference to an explanation of its origin, I repeat here from volume xxxiv the characteristics of the typical kind (not of the thinner streams that approximate to the pahoehoe), and reproduce also the sketch of a portion of one to aid the conception of its roughness: the reader's conception of it will be feeble at the best if he has not had a view of chaos already.

a. The characters of the cooled aa-stream: (1) a mass of rough blocks one foot and less to 1000 cubic feet in size, loosely piled together to a height of twenty to forty feet above the general level; (2) the blocks bristled with points but not scoriaceous, and less vesiculate than most of the pahoehoe;

Portion of an aa lava-stream.

(3) the material rather brittle, and consequently, when made up of small blocks or pieces easily broken down to a flat surface for the site of a house; (4) often aa in one part, and pahoehoe for the rest—either the chief part; (5) from one outbreak a pahoehoe-stream in one direction and an aa-stream in another.

b. The constitution and condition when in motion: (1) a mass of rough blocks outside, precisely like the cooled; (2) the motion extremely slow, indicating a semifluid condition beneath; (3) a red heat often in front among the blocks; (4)

fused rock seldom exuding; (5) the blocks of the upper part of the front, as the stream creeps on, keep tumbling down the high slope, owing to retardation at bottom from friction, and thus a rolling action in the front part.

The aa-field, owing to its crevices and shaded recesses, retains moisture, and decomposition at surface early commences, which favors germination of seeds; and often the stream, as I am informed by Mr. Baker, becomes forest-covered when the pahoehoe alongside remains bare.

One of the best published descriptions of an aa-flow is that of Judge Hitchcock (p. 31) which says: "Along the whole line of the advance, the stream, twelve to thirty-five feet in height, was one crash of rolling, sliding, tumbling, red-hot rock, no liquid rock being in sight; with no explosions, but a tremendous roaring like ten thousand blast furnaces all at work at once." Mr. Baker writes (letter of February, 1888): "I have stood by a wholly molten stream of lava which miles below was cooling into aa."

Under the restrictions of such facts the aa cannot be explained by referring it to simply a partial cooling of a stream and then a breaking up of the crust on a new accession of flowing lava—a common explanation; for there is no evidence of a crust from surface-cooling analogous to that of pahoehoe. It is not dependent on the mineral constitution of the lava; for one and the same stream may take either condition; and adjoining fields near Punaluu are at opposite extremes as to the amount of chrysolite.

The *first* conclusion we may draw, in view of the facts, and especially the abrupt transitions from aa to pahoehoe and the reverse in the flowing stream, and the independence of kind of lava, is that the difference must be connected with some condition in the region flowed over; and, the *second*, that where the transition from one kind of stream to the other occurs, the conditions must be such as will allow of extreme liquidity in one part (the pahoehoe), and occasion imperfect liquidity or a pasty state in the other (the aa).

It follows also from the size and rough character of the blocks of lava, *thirdly*, that in an aa stream the lava must have been subjected to some deeply-acting cooling agency to have made a crust thick enough for blocks 10 to 20 feet and more in dimensions—far thicker than the crust over the tunnels in a pahoehoe stream. *Fourthly*, that the cooling was not from above downward, as in the pahoehoe, for there are no remains of a crust in the true aa field, but largely from below upward; and thence comes the absence of a crust and of the usual amount of vesiculation.

These four conclusions appear to lead directly to a *fifth:*

that the region flowed over and making aa was one having more or less of subterranean moisture, since only moisture could produce the partial cooling required; not a superficial stream of water that the lava could evaporate and so put out of its way, but deeper and more widely spread moisture; and not too much for the quiet work of molecular imbibition and thereby of cooling and fracturing, with sometimes a "tremendous roaring like ten thousand blast furnaces." The aa near Hilo, of which I have spoken, was over a valley depression beneath which such an amount of moisture may well have existed. Another was along the foot of the meeting slopes of Mt. Loa and Kilauea, west-southwest of Kilauea. But my own observations were too brief to authorize a positive opinion as to the influence of the form of the surface in these cases; and in others, according to the descriptions, the surface covered by the aa is not always depressed.

There must be more or less moisture in the dark recesses of Mt. Loa. The cold summit will find enough in the air to condense at most seasons. And the percolating rains must keep the recesses damp and even make standing water wherever the rocky layers favor it. With subterranean moisture a hundred yards more or less beneath the broad lava-bed, the generated vapors would ascend into and through the liquid mass, cooling it thus from below. yet not so much the hotter bottom which receives new supplies of lava, as the portion above. The part solidified would become shattered or broken up by the tearing steam and by contraction from cooling; and, at the same time, the flow at bottom would displace and tumble together the great and small masses, giving the pile height because of the jagged forms of the blocks and the cavernous recesses left among them. This view appears to meet the demands of the facts I have observed, and all others so far as they have been published. But I present it only as a suggestion.

On this view an aa stream is literally an arate or ploughed up lava-stream; a stream ploughed up from near its bottom, so that, although vesiculated, the surface vesiculation fails, as was well shown in the stream of 1880–81 near Hilo, and in all the other cases I examined.

Dome-shaped bulges in a cooled lava stream would naturally be common over the pahoehoe part of it where the stream begins to pass to the aa condition.

The *bomb-like masses*, concentric in structure, observed over aa streams (xxxiv, 364, and in the figure on page 100), varying from an inch to a mean diameter of 10 feet, appear to be produced through the rolling movement in the forward portion of the advancing aa stream, due to friction at bottom (p. 101). They are often a heap of fragments of scoria inside with a

crust of solid lava outside, or consist of a series of concentric layers.

Dr. H. J. Johnston Lavis, who has studied with much care the Vesuvian lavas and eruptions, shows in his paper on "Fragmentary Ejectamenta of Volcanoes,"* that the "volcanic bombs" of writers on European volcanoes are not bombs any more than those of Mt. Loa; that they were not projected into the air; that they occur scattered over lava streams in great numbers when the adjoining country is free from them, and occur within lava streams; that they vary in size from a walnut to some cubic yards, and yet have often a thin shell and friable nucleus; that they "occur most commonly by far on the surface of lava-streams whose surface is rough and scoriaceous, instead of corded." He regards them as formed of lapilli that fell upon the flowing lava, and "in consequence of its forward motion became incorporated with it, and may undergo partial fusion, but usually congeal around themselves a coating of the parts in which they are involved." The description shows that the bomb-like masses of Hawaii are essentially identical in origin with the "volcanic bombs" of Europe. *Ejected blocks* are, as Dr. Johnston-Lavis remarks, wholly different in origin.

4. *Lateral Cones.*

Lateral cones are a frequent result of eruptions on Hawaii and the other islands of the group, although the lavas are basaltic. They occur, as in other volcanic regions, along the courses of fissures; along a flow of lava where fissures for supplying lavas are underneath it; and also in and about the summit crater. Whether they consist of lava-streams, or of cinders (lapilli) depends on the supply of heat as well as of lava in the vent (xxxv, 28); and whether the cinders make cinder-cones or tufa cones, on the supply of moisture connected with the eruption, much descending moisture giving a mud-like flow to the ejected cinders, whence the low angle and saucer-like crater of the tufa-cone.

They appear to be most common over the lower portion of a lava-stream, toward or along the sea-border; and it may be that this is due to the presence of more subterranean waters about the lower or foot slopes. A lateral cone of either of the three kinds is good evidence of a fissure beneath as a source of the ejected and pericentrically deposited material; and this evidence from them gives their occurrence especial interest. Where a stream of lava enters the sea and makes a cone of cinders or lava, there must be a fissure to supply the lavas and

* Proc. Geologist's Assoc., London, ix, No. 6.

projectile vapors, and thus to produce the upward throw of cinders and the pericentric deposition and stratification which are the marked features of a lateral cone. No such shape or structure can come from the simple discharge of a lava-stream into the sea, however rapid its progress; for this merely puts the fragments that are made at the disposal of the waves or currents along the coast, and the heaps piled up will be such as the action of waves and currents may make elsewhere. It cannot imitate successfully the pericentric work of the volcano. For this work, a center of ejection, acting for successive days or weeks, is required.

2. EXPLOSIVE ERUPTIONS.

All the eruptions of Mt. Loa and Kilauea within the last 65 years, the period of actual history, have been, as has been stated of the ordinary kind, that is quiet ouflows. At each, the lavas of the crater have simply quit work and sunk out of sight; and the discharge thus begun, with the consequent down-plunge of the undermined floor, was nearly all there was of eruption so far as the crater was concerned.

But traditional history gives hints of an eruption in 1789—a century back within a year—of another kind; and the results are visible over the region around the crater of Kilauea, as already described (xxxiv, 359). Similar evidences exist of an explosive eruption in the summit crater, as may be inferred from the descriptions of Mr. Brigham (p. 23) and J. M. Alexander (p. 31), as well as the earlier of Captain Wilkes,* and also in that of Hualalai.

In the cases here referred to, the ejected material includes solid masses of the basalt, much of it very compact, and some of the blocks 50 to 100 cubic feet in size. For such work, instead of a cessation of the ordinary projectile action of the crater and a quiet discharge of the lavas when the eruption began, there must have been an enormous increase of projectile power, with great rendings of the rocks within reach of the up-thrust action. The eruption was not a quiet outflow, but a catastrophic up-throw. Whether accompanied or not by an outflow of lava is unknown.

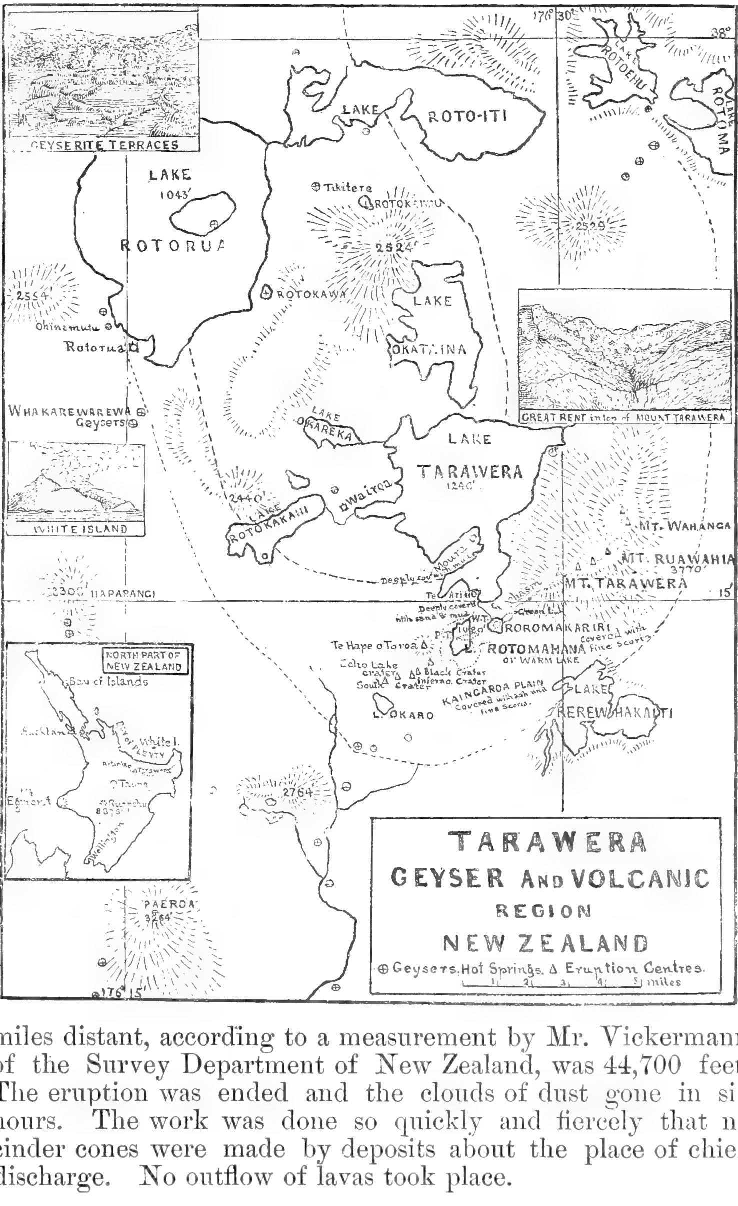
Examples of explosive eruptions from Tarawera in New Zealand, and Krakatoa an island just west of Java, will make clear what is meant distinctively by an explosive eruption.

In 1886, in the Tarawera geyser region after some earth-shocks, a projectile eruption of terrific violence and incessant

* Wilkes speaks of large bowlders of a grayish basalt at the summit which had apparently been ejected from the crater (p. 159).

The precise date of the Kilauea eruption is in some doubt.

detonations began. Scoria and volcanic ashes or sand were thrown to a great height, that drifted with the wind and covered the country thickly and far away with ashes, making darkness, over a breadth of several miles, all the way to the sea in the Bay of Plenty. The height as seen from Auckland, 130



miles distant, according to a measurement by Mr. Vickermann of the Survey Department of New Zealand, was 44,700 feet. The eruption was ended and the clouds of dust gone in six hours. The work was done so quickly and fiercely that no cinder cones were made by deposits about the place of chief discharge. No outflow of lavas took place.

The accompanying map and explanations will make the remarkable Tarawera events more intelligible.* It represents the Tarawera geyser region, its lakes, mountains, and other features. A small map to the left shows the northern New Zealand island, and the site of Tarawera in the N. 35° E. volcanic line of Ruapehu, Lake Taupo and White Island; and White Island is represented in its usual steaming condition in a sketch just above. The line of the eruption in 1886 extended in a N.E.-S.W. course from Lake Okaro through Mt. Tarawera and Mt. Wahanga. Lake Rotomahana at the time of the eruption was emptied and converted into a region of craters. This lake, previous to the eruption, had on either side, a geyser basin and one of the famous geyserite terraces of New Zealand; the "Pink terrace" on the west (PT on the map), and the larger and more beautiful "White terrace" (WT) on the northeast side with the geyser Te Tarata at its head. The outflowing waters of Te Tarata, descending the gently sloping surface to the lake, had covered an area eleven and a half acres in extent with its siliceous (or geyserite) depositions, forming a descending succession of whitish cream-colored and almost porcelain-like terraces. A view of a portion of the terrace is given in the left upper corner of the map. Both terraces were buried in volcanic mud and ashes, a mud volcano displacing the geyser basin. A sketch to the left represents (from a photograph by Mr. C. Spencer), the region of the "great chasm," 200 yards and more wide, made in the Tarawera range at the outbreak; and the map gives its position, and also the positions of the several centers of eruption along the region. The outer dotted line on the map encloses the part of the Tarawera region that was covered with volcanic ashes, mud and scoria, and the inner, the portion of the larger area that was buried beneath mud; and the latter includes the buried villages of Te Ariki, Moura and Wairoa, where there was destruction of life, as well as a general obliteration of houses. Subsidences continued to take place along the great opened fissures for weeks after the eruption had ceased.

At Krakatoa, in 1883, the projectile discharge was equally sudden, and far more terrible and destructive. The height to which the dust was carried was made by Professor Verbeck 50,000 feet. It began in the early morning of one day, made day into night (by its ejections of ashes) for 36 hours, and left the sky clear by the close of the next day. Nothing is said of an outflow of lavas.

The earthquakes at Tarawera were not violent; they were felt to a distance of 50 or 60 miles only; and a dozen miles from Tarawera Mountain, at Rotorua, on the geyser plains, no shock was able to upset a chimney or jar down crockery from

* The facts here given are from an account of the eruption by T. W. Leys, 56 pp. 8vo, with maps and other illustrations, Auckland, New Zealand, and the Report of S. Percy Smith, Assistant Surveyor General, 84 pp. 8vo, Wellington. The height of the ejections above given is cited from the latter work, page 29.

a shelf. They were manifestly local, and had their center near the surface—an effect, not a cause; and they thus prove that the immediate cause of the eruption was local. The facts as to the Krakatoa earthquakes are similar. The deafening roar in each was made chiefly by the violent projectile action, the incessant detonations and the thunderings of a storm.

Such eruptions are of a wholly different cast from the ordinary outbreaks and discharges of Hawaii. The projectile agent must gain access to the conduit lavas to produce such extraordinary violence.

The eruption of Tarawera Mountain was probably brought about by the opening of a fissure that let subterranean waters *into* the reservoir of lavas; for Lake Rotomahana, situated on the line of fracture and only three or four miles distant, lost its waters, and probably in the process of supplying water for the projectile work. The volcanic mountain had been long extinct; but the widely distributed geysers and boiling springs were testimony to the existence of liquid lavas just below the reach of descending atmospheric waters. The geyser lakes of Rotorua and other localities became hotter during the night of the eruption and continued so afterward. Under such conditions an old volcanic mountain, perhaps hollow from former discharges, might be burst open again. Had the ingressing waters passed into the lava-reservoir *at a great depth* below the surface, the generated vapors would necessarily have added outflows of lava to the projectile discharge.

The volcano of Krakatoa, was probably started into action by a similar incursion, but of marine waters.

In both cases there were enormous chasms and crater-like depressions made, with a loss of the old foundations, and of the rocks that occupied the depressions. But the facts, while they include the projection of large stones over the vicinity, show positively that the stones were few compared with what would be needed to fill the great cavities left in the region. The explosive eruption blew to great heights fragments of the liquid lavas in the shape of scoria and sand or ashes, but did not blow off the solid rocks of the mountain. The disappearance of these and the making of the cavities are explained by the engulfment or down-plunge of material *to fill the space left empty* by the projectile discharges.

An *explosive eruption* is then simply one in which the projectile action, instead of ceasing at the time of eruption, becomes enormously increased; in which the erupting agent, instead of being roused to action outside of the lava-conduit, gains access to its interior, and hence the terrific boiler-like explosion.

For further explanation I repeat that the *ordinary activity*

of a volcano consists in the more or less high projection of cinders or of liquid lavas, with usually a great increase in the height as the crisis of an eruption approaches. In such action, there is nothing of the explosive work above described; neither is it entitled to be called a state of eruption; it is only a state of activity. Stromboli is perpetually at work in the *ordinary* way, with great variations in activity, "exhibiting the nature of volcanic action in its true light;" but it is not in "perpetual eruption;" no true eruption of this volcano, non-explosive or explosive, has been recorded in recent times. A volcano often gasps out its life in cinder ejections; for this is the meaning of the summit cinder cones of Kea, Hualalai, and Haleakala. It is still true, however, that cases occur in which it is difficult to decide whether the condition is that of ordinary activity or of true eruption.

The results of the projectile eruption of Kilauea, mentioned in the earlier part of this paper (xxxiv, 359–361), need not be here repeated. We learn from the deposits made by it that the eruption began in bombarding style—the projection of great stones to a distance of one to two miles, ranging to a height a thousand or more feet above the place of discharge; and ended in a widely extended shower of scoria and ashes. The finer material, besides covering all the borders of Kilauea, spread for miles to the southeastward, southward and southwestward. It constitutes, as I learn from Mr. Baker, the sand of the Kau "desert" described as ten by fifteen miles in area, and makes the bed, for six or eight miles, of an excellent carriage road between the crater and the ranch nearly half-way to Keauhou.

The evidence that the great stones were from the throat of the lava-conduit and not from the walls of the crater consists in their comprising, both east and west of Kilauea, kinds not found in the walls; and also many blocks of lava whose vesicles are lined with minute crystals of pyroxene and a plagioclase feldspar (as determined by Professor E. S. Dana), which are proof of subjection to long-continued heat. The walls of Kilauea are out of the reach of such upthrust or projectile action.

The explosive eruption of the summit-crater is of unknown date. As some of the ejected stones are fifty pounds to a ton in weight, it was probably similar in character to that of Kilauea; but the facts need further study.

Explosive eruptions at Kilauea and Mt. Loa are exceptional occurrences. In my examinations of the well-stratified walls of Kilauea I found evidence only of layers of lava—that is of old lava streams. But thin beds of stones and scoria might occur at intervals without making much impression on the

mountain or leaving very apparent traces in the walls. The summit crater, as described by visitors, has, like Kilauea, walls made of the edges of lava streams, without intercalations of prominent beds of scoria or other fragmental material.

II. Metamorphism an Effect of Volcanic Conditions.

The projected rocks of the region about Kilauea are a prominent source of evidence as to metamorphism by means of volcanic heat—as remarked on page 289 of volume xxxv; and other facts of like import are derived from the lava-stream tunnels and caverns. The rocks referred to, and those also of the lavas generally, as well as the cave-products, will be described by Mr. Dana in a following part of this volume. I briefly mention here a few of the facts that have a special bearing on metamorphism.

1. The minute crystals in the cavities of the ejected masses, instead of being zeolites, such as exposure to the weather might have produced, have been proved by Mr. Dana, as has been stated to be identical with the anhydrous constituents of the lava. Minute transparent acicular crystals have given him the angles of pyroxene; white rhombic tables, the characters of a triclinic feldspar, so that they are probably labradorite; and besides, there are brilliant iron black octahedrons of magnetite and tables of hematite or titanic iron. These are all the constituents of the basalt except the less constant one, chrysolite.

2. The caves and tunnels of Kilauea and of the Mt. Loa lava-stream of 1880–81, afford stony stalactites, remarkable for their slender pipe-stem like size and form, scarcely tapering at all except at the extremity, where there is usually a short irregular twist. The diameter is hardly a fourth of an inch. In 1840 I found only short specimens in the caves of Kilauea; but in 1887 in the tunnel of the lava of 1880–81, near Hilo, many were 20 to 30 inches long; and in some undisturbed parts of the tunnel there were thickets of these, long gray-black stalactites, one every six or eight inches. Over the floor beneath each, there is a column of stalagmite of similar nature, which is a heap of bent coalescing drops or anastomosing stems from a few inches to fifteen or more in height. Most of the stalactites were solid, with occasional cavities, but many were tubular. Mr. Brigham observed them in the Kilauea caves in 1864–5, and has good figures on page 463 of his Memoir.

These stony stalactites appeared, under a pocket lens, to be identical with the rock of the lava-stream, even to the laths of labradorite, and the cavities showed minute transparent acicu-

lar and tabular crystals, besides black octahedrons of magnetite. The microscopic investigation of Mr. Dana proves that they actually are like the lavas in constitution, and that the crystals are of pyroxene and feldspar as in the ejected blocks.

The origin of the stalactites of the tunnels and their crystallizations is due, as I state in my Expedition Report (p. 201), to "the action of steam on the roof of the cavern." In the case of the tunnels the flowing lavas left behind a chamber filled with superheated steam, and under its action the solution and recrystallization went forward.

This reproduction of the basalt and the making of the crystals in geodes, or as linings of fissures, are examples of metamorphic work. It is metamorphism of the *crystallinic* kind*, the same which takes place when a feldspathic sandstone is converted into granite or granulyte, or when calcyte is changed into marble; and it is therefore one of the common kinds of metamorphism.

4. The ejected blocks about Kilauea instruct us on another point of much geological importance. They show that the throat of a volcano is necessarily a region of metamorphic action. It is a region of continued heat; and heat always works change when moisture is present. Under such conditions, therefore, an Archæan limestone or other Archæan rock containing chondrodite, spinel, vesuvianite, scapolite, anorthite, nephelite, biotite, might lead to the production of recrystallized chondrodite (humite), spinel, vesuvianite, scapolite (meionite), anorthite, nephelite, biotite (or meroxene) as metamorphic results; and in just the situation where an explosive eruption might detach masses and bring them up to the light. It is noteworthy that the above minerals of the ejected blocks about Somma, which have long been regarded as throat minerals of Vesuvius, crystallized by the volcanic heat as held by Scacchi, are kinds that are characteristic of Archæan rocks and especially of an Archæan limestone, rocks which may underlie the later limestones and other strata. There is little assumption therefore in saying that some of these crystallizations illustrate specifically crystallinic metamorphism, though others may be of the metachemic kind, that is, products of chemical change.

From the side of a fissure near the bottom of the emptied basin of the lava-lake called the "Old Beggar," was taken, at my visit in August, 1887, a specimen as large as the hand, covered with minute white tabular crystals, with some transparent crystals of acicular form. The mineral turned out to be gypsum, common as an incrustation in Kilauea caves.

* "On terms applied to metamorphism," this Journal, III, xxxii, 70, 1886.

III. The form of Mt. Loa a consequence of its Eruptions.

Mt. Loa differs from almost all other volcanic mountains in having a double curvature in its profile, owing to the flattening and widening of its summit, and the spreading of its base. It is the flattened summit which gives so vast bulk to a mountain of its altitude.

This peculiarity I attributed in my Expedition Report, to the positions of the prevailing outflows, on the ground that discharges of lavas about the base tend to widen and flatten the base and give a single concavity to the profile on either side; that discharges at the summit, especially if in short streams, serve to elevate the summit and make still more pronounced the single concavity; but that discharges over the upper slopes and not over the summit, tend to widen the upper part and flatten the summit so as to produce a convexity in the profile above.

The outflows of the century have had the distribution required to produce the actual form. Part are basal; another large part start just below the summit, and none of much size from the vicinity of the summit crater. The double curvature so produced, however, is mostly confined to the eastward and south-southwestward slopes, the chief directions of expansion by basal outflows; moreover, the widening in the former direction owes much, beyond doubt, to the eruptions of Kilauea. Further: *owing to the absence nearly of cinder-ejections*, the summit fails of the most common means of growth in height with tapering top; and this is a prominent source of the difference between it and most other volcanic mountains.

Another cause tending to modify the shape of the mountain is that producing fractures and subsidences. Its effects are seen about the great craters, and still more pronounced about the borders of the island. The former action aids in making summits broad and flat, while the latter works directly against the widening of the coast region. It makes the greatest fractures, nearly parallel with the coast and drops the coastward block; it thus tends to shorten the radius of that part of the mountain and put precipices into its profiles, increasing thereby the mean slope. Two such walls in southern Hawaii, cross the road between Keauhou and Kilauea, one about a mile and a half from the coast and the other three miles; they are marked features before the traveler in his ride from the coast to the volcano. These faultings seem to be a reason for the concavity in the southern coast-line from Keauhou westward, and for the short distance in that direction between the summit and the coast. Other great fault-planes exist; but the government map of the island should be completed before the facts can be satisfactorily discussed.

Sagging from pressure and consequent crushing has been made a cause of a single concavity between the top and the base of a volcanic mountain, and mathematical calculation has found a conformity between physical law and the shapes of such mountains in Japan and America. But there can be no crushing from gravitational pressure in a mountain made almost solely of lava; and it is hardly a possible result in any existing cone if made up even one-half of lava-streams, braced as they are by dikes.

The following are the mean slopes of Mt. Loa from the summit along different radii. The distances made the basis of the calculations are taken from the Government map:

S.S.W. to the southern cape	1 : 13·1=4° 22′
S.E. by S. to the indented Kapapala shore	1 : 9=6° 20′
S.E. to foot of slope W. of Kilauea	1 : 9·12=6° 15′
E.N.E. to shore at Hilo	1 : 14·86=3° 51′
W. by S. to western shore	1 : 8·11=6° 43′
N. by E. to plain between Loa and Kea	1 : 9 to 1 : 10=5° 50′ to 6°

In a circle of five miles around the summit crater the mean slope is about 3°: the mean depression to the eastward at the perimeter of the circle is about 1400 feet.

From Kilauea to the eastern cape, 28 miles, the slope is 1 : $36\frac{1}{3}$ =1° 35′.

The fact that Mt Loa as well as Kilauea were made over a great fissure has given an oblong and approximately elliptical or ovoidal form to all the upper contour lines of Mt. Loa. Further, the bend in the longer axis of the summit crater, making the concavity to the eastward, is also expressed, according to the large government map, in the form of the upper part of the dome.

At what period in its history, Mt. Loa left off superfluent discharges and took to having only the *effluent*, or those through fissures, it is impossible to say. But as the walls both of Kilauea and the summit crater are made up of the edges of lava-streams to the very top, it would appear that summit overflows from the crater may have continued in each to a comparatively recent time. It is remarkable that the north and west walls of Kilauea, which show well the stratification from top to bottom, have almost no intersecting dikes.

In the following paper, the relations of the Kilauea volcano to Mt. Loa will be considered, and the question as to the effects of volcanoes on the depths of the ocean.

[To be continued.]

ART. XII. — *The Fayette County, Texas, Meteorite;* by J. E. WHITFIELD and G. P. MERRILL.*

THE meteorite described below was found some ten years ago at Bluff, a settlement on the Colorado River about three miles southwest of the town of LaGrange, in Fayette county, Texas. Bluff cannot boast of being a village as it is simply made up of a few farms scattered within a radius of two miles. The farmers are mostly Germans or Bohemians, and as they are generally of the superstitious class, it is not strange that the finder, a Bohemian, named Raniosek, should have been struck by the appearance of the stone, and especially by its weight. As it is probable that he never heard of such a thing as a meteorite it is safe to say that he did not know the nature of his find; still he seems to have come to the conclusion that it was something foreign to the soil.

There is a tradition in Fayette County that Santa Anna, at the time of his flight after the battle of San Jacinto, buried his war-treasures somewhere near LaGrange, and the belief has so fixed itself in the minds of the inhabitants that many fruitless attempts have been made to discover it. The finder of the meteorite, with the tradition fresh in his mind, reasoned that so large and heavy a stone must mark the place where some treasure was deposited; he therefore rolled the stone a few feet aside and dug a deep hole at the exact spot where the stone had been, without finding anything to pay him for his labor.

For several years the stone lay where the Bohemian had left it; then he sold the piece of land to Mr. C. Hensel, who still owns it; but before the latter had taken possession, Raniosek removed the stone to his own farm, about a mile away, where for five years more it lay neglected in his yard. His reason for removing it was that its weight led him to suspect it contained some valuable metal.

About three years ago Mr. H. Hensoldt took charge of the school at Cedar, two and one-half miles from Bluff settlement. By spending his spare time in hunting over the ground for fossils, minerals, etc., the attention of the farmers was drawn to him, and in January, 1888, he was informed of the strange stone in Mr. Raniosek's yard. Immediately on seeing it he recognized it as a meteorite, and a very fine specimen of its kind.

After obtaining possession of the stone Mr. Hensoldt disposed of it to Messrs. Ward and Howell, of Rochester, N. Y.,

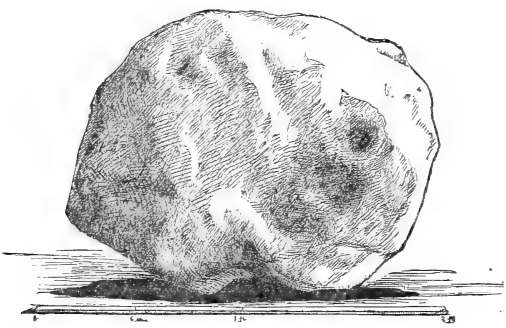
* The chemical work was done in the laboratory of the U. S. Geological Survey; the petrographical work in the laboratory of the U. S. National Museum.

to whom we are indebted for the material for study and the privilege of description. On receiving the stone, Mr. Howell published a notice in Science (Feb. 3, 1888, p. 55) putting it on record as the "LaGrange Meteorite," but on finding that this name had already been applied to the Oldham County, Kentucky, meteorite, agreed that it should be called the Fayette County Meteorite.

The stone possesses all the characteristics of a meteorite. The pittings are well marked, but the crust shows only in the deeper depressions; a freshly fractured surface shows, besides the grains of metal, a greenish gray appearance not unlike some greenstones. A particularly interesting feature of the stone is the presence of a few dark-colored veins varying greatly in dimensions—the one in the specimen for examination being some 2^{mm} in greatest width, and 60^{mm} in length.

The three dimensions of the mass are $58^{cm} \times 46^{cm} \times 28^{cm}$, and the total weight about 146 kilos. A good idea of the appearance of the meteorite may be had from figure 1.

1.



Before the specimen was pulverized for analysis the vein was carefully sawed out so as to keep all the vein material from the mass. The rock was then ground as fine as possible, and a portion (1 gr.) treated with iodine in cold water, to separate the metallic particles. The residue was filtered on a Gooch soluble filter and washed free of iodine. The rocky material after being weighed was treated with dilute hydrochloric acid and allowed to stand for some time, then filtered and the residue weighed. In both cases the mineral being separated from the filter by using the proper solvent for the anthracene—washed with ether and alcohol and dried at 100° C. This temperature not being sufficient to drive all the water from the mineral part accounts for the discrepancy of about 2 per cent.

The following figures will show the composition of the metal and the rock, soluble and insoluble, in hydrochloric acid; also the results of a complete analysis of the total mass:

	No. 1. Total mass.	2. 5·67 per cent total. Metal.	3. 33·3 per cent of total. Insol. in HCl.	4. 60·62 per cent total. Sol. in HCl.
SiO_2	= 37·70		49·64	33·59
Fe	3·47	82·42	----	----
FeO	23·82		15·56	31·12
Al_2O_3	2·17		4·12	1·34
P_2O_5	·25			·42
CaO	2·20		4·93	1·00
MnO	·45		·54	·43
MgO	25·94		25·21	28·08
NiO	1·59		trace.	2·66
Ni	·65	15·44	"	
CoO	·16		"	·27
Co	·09	2·14		
S	1·30			2·18
	99·79	100·00	100·00	101·09
Less O, for S,	= ·65			= 1·09
	99·14			100·00
Sp. gr. = 3·510.				

The percentages in all except the first are calculated from the weight found.

From these figures it will be seen that the minerals which go to make up the rocky portion of the meteorite are essentially olivine and enstatite, with considerable pyrrhotite, as is also shown by the microscopical description.

The stone belongs to the class of meteorites to which G. Rose* has given the name "chondrites." To the unaided eye the chondritic structure is not distinctly marked, a broken surface showing a fine grained and evidently crystalline-granular rock, very compact, of a greenish gray color and thickly studded with small metallic points with a brassy luster. A polished surface shows the stone to be composed of small chondri rarely over 2^{mm} in diameter, thickly and firmly compacted in a fine granular groundmass. Throughout the entire mass are thickly distributed innumerable small irregular flecks of a steel-gray, brassy and bronze-yellow color, presumably native iron and pyrrhotite.

The striking feature of the stone is its fine and compact texture, which exceeds that of any chondritic meteorite with which we are acquainted, but which is perhaps most closely approached by the stones of Dhurmsala, India, and Cabarrus county, N. C.

Thin sections of the stone show, under the microscope, a confused aggregate of rounded and irregular, often fragmental olivine and enstatite grains and chondri, imbedded in a fine granular groundmass of the same mineral composition.

The chondri occur in both monosomatic and polysomatic forms composed either of olivine or enstatite alone or the two

* Abhandl. der Königl. Akad. d. Wissensch. zu Berlin, 1863, p. 161.

minerals associated. The peculiar grate-like or barred forms so characteristic of olivine chondri are here represented, as are the radiating fan-shaped forms of enstatite.

The large greenish microscopic chondri are, under the microscope, seen to be made up of innumerable enstatite granules so arranged as to form oval or fan-shaped areas of radiating columns enclosing large, quite perfectly outlined crystals of the same mineral. These included forms are nearly colorless or merely gray through enclosures of innumerable dust-like particles, and show sharp and well defined cleavages parallel to either prism, and a parting parallel to the orthopinacoid. Both olivine and enstatite are nearly colorless or gray through enclosures of dust-like particles, and carry but few cavities.

In addition to the minerals above mentioned there were noticed occasional broad, irregular plates of a monoclinic mineral, light gray in color but polarizing brilliantly in red and yellow colors and which gave extinction angles varying from 25° to 31°. Such are presumably augite or a closely allied pyroxene. Nothing that can be certainly identified as a feldspar was observed. Occasional small, nearly colorless, angular forms show faint indications of twin structure, and it is possible may be a plagioclase. In two sections were observed irregular outlined interstitial areas, perfectly colorless and full of gas cavities. These in some cases remained quite dark during a complete revolution of the stage, and in others gave decided polarization in light and dark colors, and in converging light showed indistinct biaxial interference figures. The position of these areas relative to the other constituents is that of an interstitial glass or a secondary mineral, like a zeolite. As they show neither cleavage nor crystallographic outlines, and moreover are to be found but rarely in the sections at hand, it is impossible to identify them satisfactorily.

2.

Natural size.

The metallic iron occurs in the usual rounded and irregular masses one to two millimeters in diameter and is apparently in about equal proportions with the pyrrhotite: the latter showing a bright brassy luster in strong contrast with the silvery white iron.

The black vein above noted traverses the stone in the form of an irregular fissure (often expanding and contracting abruptly as is shown in figure 2), for a distance of about 60^{mm}, and varies in width from a mere line up to 2^{mm}. Near its lower end it bifurcates and encloses a portion of the mass of the meteorite some 15^{mm} long by 2^{mm} wide.* From a fragment

* Since the above was written Messrs. Ward and Howell have sliced the stone through the center and published in Science of June 1, 1888, a figure showing the full extent and width of the veins.

containing a portion of the vein thin sections were prepared, and the remaining vein material, separated as clearly as possible from the enclosing rock, was subjected to chemical analysis, the process being essentially the same as in the analysis of the meteorite proper. Although the vein material is more compact and much darker in color, the analysis shows very little difference from that of the mass, the main apparent difference being the absence of the lime-bearing mineral. The following are the figures obtained by analysis on material that weighed a little less than 0·4 grams:

Metal.			44 per cent of vein. Insoluble in HCl.	51 per cent of vein. Soluble in HCl.
Fe	= 2·30	SiO_2	= 56·52	27·63
Ni, Co	trace	FeO	12·35	34·31
		Al_2O_3	1·51	2·41
		CaO	trace	trace
		MgO	25·53	32·12
		(NiCo) O	4·09	3·27
		S	----	·52
			100·00	100·26
			Less O, for S =	·26
				100·00

Sp. gr. = 3·585.

The same difficulty, with regard to water in the mineral, exists here as in the analysis of the mass.

From the figures it appears that the portion soluble in hydrochloric acid is essentially olivine in composition, while the insoluble is evidently a mixture of the same insoluble constituents as the mass of the meteorite. The filling material of the vein is, to the unaided eye, quite black and without luster; under the microscope it is seen to penetrate very irregularly and by innumerable minute vein-like ramifications into the stony mass on either side and to carry numerous enclosures of a colorless mineral substance and blebs of metallic iron and pyrrhotite. The exact nature of the colorless enclosures cannot be ascertained. On treating an uncovered slide with hydrochloric acid a part of these were dissolved, others were unacted upon. Under the microscope they are full of irregular rifts and fracture lines but show no true cleavages. Some of them are in the form of single individuals, others have the structure of fragments of polysomatic chondri. Nearly all contain included black amorphous material and many show distinctly included specks, giving the silvery white and brassy yellow reflections of the metallic iron and pyrrhotite. In many cases they are not separated from the black vein material by sharp lines but seem to pass into it by gradations. Between crossed nicols many of them act like a gum, others remain always light, recalling the well known crypto-crystalline

structure of chalcedony and still show, here and there, occasional small areas giving the characteristic polarization colors of olivine and enstatite. On examining the walls of the vein, areas were observed where the gray and yellowish enstatites and olivines retained their normal properties at the distance of one or two millimeters, but at contact with the black vein matter were reduced to the colorless non-polarizing condition of the enclosures.

The black matter of the vein when viewed in strong reflected light shows a dull bronze luster, less brilliant than that of the pyrrhotite particles which it encloses. The thinnest portions of the slide when examined with a power of 175 diameters show a brownish amorphous base through which are scattered abundant irregular dust-like particles and flecks of a perfectly black opaque material, the nature of which it is impossible to ascertain by the microscope alone.

The structure of the vein is shown in figure 3 in which the finely dotted portions represent the black amorphous vein matter with bronzy luster, the entirely black area, the blebs of metal and pyrrhotite, and the irregularly rounded, clear or partly clouded area, the colorless silicates.

3.

Portion of vein highly magnified.

From the study of these veins as above described, we are inclined to consider the colorless particles as olivine and enstatite residuals which have been deprived of their normal optical properties by the forces active in forming the vein. What the exact character of the black and amorphous material may be, still remains a matter of conjecture. It is unacted upon by acids and when tested with a needle point it breaks up readily into earthy fragments which are not attracted by the magnet.

Mr. Howell informs us that the stone in his possession shows three of these veins, the largest exposure of any one on a broken surface being about four inches. The width and general character of all, he states, appears to be uniform throughout, though this can be ascertained definitely only by breaking the stone.*

* In structure these veins seem to only remotely resemble those described by Tschermak (Sitz. der Kais. Akad. der Wiss., lxxxv, 1, p. 204), in the Mocs meteorite and which, it will be remembered, he argued indicated an elevation of temperature since the consolidation of the stone, such as aided by reducing vapors and gases fused the iron and pyrrhotite without affecting the silicates. He describes the brown and black "Fullmasse" of the vein as an admixture of the same sub-

Owing to the small amount of vein material which was available for chemical analysis and the impossibility of separating it completely from the enclosing rock, the results obtained can be regarded only as suggestive. The main points brought out can be best shown by reproducing here a comparison of the results:

	Mass of meteorite.	Vein material.
SiO_2	= 37·70	38·96
Fe	4·41	2·30
FeO	23·82	22.98
Al_2O_3	2·17	1·89
CaO	2·20	trace
MnO	·45	----
MgO	25·94	27·52
Ni Co	1·75	3·26
S	1·30	·26
Sp. gr.	= 3·510	Sp. gr. = 3·585

These differences are too slight to be considered of great value until found to be constant by further investigation. It is to be hoped that the ultimate possessor of the stone will regard a knowledge of its true character as of first importance and will not hesitate to sacrifice any necessary amount for the purpose of an exhaustive examination by the most advanced methods. Our most sincere thanks are due Mr. Hensoldt for kindly furnishing us with the information regarding the discovery of the meteorite.

Washington, D. C., April 12th, 1888.

Art. XIII.—*Evidence of the Fossil Plants as to the Age of the Potomac Formation;** by Lester F. Ward.

It is remarkable that the geologic age of the formation upon which the cities of Baltimore, Washington, Fredericksburg and Richmond stand should have remained unknown to the present day. My contribution to this subject relates en-

stance as the meteorite itself, and an opaque, half glassy black admixture resembling the black vein-like material of the Orvinio stone. The silicates occur in the vein in the form of small sharp splinters, the iron in granules and the pyrrhotite in the form of little leaves and small kernels, often so arranged as to give rise to a fluidal structure. Dr. Hans Reusch has described (N. Jahrb. für Min., iv Beil. Band., 3d heft, 1886, pp. 491–2), veins in the Ställdalen meteorite which present features in part common to those of the Fayette stone. To the unaided eye the filling material is black and opaque and carries metallic particles. Under the microscope it shows a brownish gray, isotropic and sometimes opaque glassy substance densely crowded with rounded transparent fragments. The upper figure in his Plate XIV closely resembles in structure the vein matter of the Fayette stone, but as far as can be judged from his description the included particles seem to have retained their normal optical properties. Reusch regards this black vein material as the result of a partial refusion of the chondrite substance.

* Read before the National Academy of Sciences at Washington, April 20, 1888.

tirely to the evidence which the vegetable remains found in that formation furnish toward the solution of this question. Until quite recently this was the only paleontologic evidence attainable, but within the past six months vertebrate remains have been found which are of the highest value. Indeed, with the exception of a few ferns obtained by Mr. F. Shepherd near Fredericksburg, Virginia, and figured with very imperfect descriptions in a paper by Richard C. Taylor, published in the Transactions of the Geological Society of Pennsylvania, in 1835,* it is only within the past five or six years that the existence of plants, other than silicified wood and lignite, in this formation has been made known. For their discovery, thorough investigation, and careful elaboration, we are almost wholly indebted to Professor Wm. M. Fontaine, of the University of Virginia. Four years ago, Professor Fontaine brought to Washington some specimens collected at Fredericksburg in what he then regarded as Jurassic strata, which, though quite imperfect, he had observed to differ from all the ferns, conifers and cycads of true Jurassic type, and to resemble in many respects dicotyledonous leaves.

Although aware that certain ferns, such as Dictyophyllum, Thaumatopteris and Clathropteris, having decidedly net-veined fronds, have been found in Jurassic strata, nevertheless, so different were these leaves from such forms, and so similar were they to modern deciduous leaves, that I expressed at the time my conviction that they were true Dicotyledons, though of an archaic type; and speaking of them in my article on Mesozoic Dicotyledons, in this Journal for April, 1884, I said (p. 303) that they "certainly possess all the essential elements of Dicotyledonous leaves, although at the same time bearing a certain recognizable stamp of the cryptogamic and gymnospermous vegetation that characterizes that earlier age."

As the subclass Dicotyledons, formerly called angiospermous Exogens, had at that time, with the exception of a single somewhat doubtful species, never been found lower than the Cenomanian of France, Quadersandstein of Germany, Middle Creteceous of Greenland, and the Dakota Group and Amboy clays of the United States, all of which are usually regarded as nearly equivalent in age and as representing the middle member of the Cretaceous above the Gault, my interest in this apparently great downward extension of this class of plants was from the first of the liveliest character, and I have from that day not only watched eagerly the progress of Professor Fontaine's investigations, but have accompanied him on several of his collecting tours through the States of Virginia, Maryland and North Carolina, and have carefully studied the beds hold-

* Vol. i, pp. 320–325, Pl. XIX.

ing the plants, the character of the specimens in place, and the general nature and affinities of the flora of the Potomac formation.

In the course of this investigation the accuracy of my conjecture as to the true nature of the forms I have mentioned has been abundantly verified, and we have now, described and figured by Professor Fontaine, no less than seventy-five species of undoubted Dicotyledons in this flora. These forms, together with a number of others to which I shall presently refer, have led Professor Fontaine to change his mind slightly as to the age of this formation, and instead of Jurassic, as first believed by Rogers, he now, as I understand, inclines to adopt the later view of that authority that they are Jurasso-Cretaceous and will prove to form a group of passage beds between the Jurassic and Cretaceous, similar to the Wealden of Europe. Professor Fontaine, however, prefers to call the flora Neocomian, which he gives a wide range as including all the older Cretaceous from the Gault downward, and of which he regards the Wealden as an equivalent fresh-water deposit.

My object in the present paper is simply to show, in as clear and direct a manner as possible, what the fossil plants of the Potomac formation indicate as to its age, and I shall not advocate any special view of the case.

With the exception of five species described by Professor F. H. Knowlton from a study of the internal structures of the silicified wood and lignite, in a paper soon to be published,* it is to Professor Fontaine that we are exclusively indebted for the details which I have summarized in the present paper. At the expense of vast labor he has studied, described and delineated the extensive collections made almost entirely by himself, and has prepared an elaborate manuscript, with 174 plates, which has not yet been published. He has very kindly placed this unpublished work at my disposal, and it is from it that I have chiefly compiled the data which I have to present. Without such a compilation it would be impossible to determine the precise relations of this flora to those of other formations. Professor Fontaine seems not to have undertaken such a compilation, and must have depended for his opinion of the age to which the flora points upon the impression made on his mind by each species separately and that produced in his memory by the *tout ensemble.* Considering this, it is certainly remarkable how accurate his judgment was, and I am not prepared to affirm that the conclusions which flow mathematically from the statistical view here presented, taken in themselves, differ in any marked respect from Professor Fontaine's intuitions.

* Bulletin U. S. Geological Survey, No. 53.

Elements of the Potomac Flora.

	Equiseta.	Ferns.	Cycads.	Conifers.	Dicotyledons.	Uncertain.	Total.
Number of Genera	1	19	11	19	29	1	80
" New Genera		3	2	7	19		31
" Species	3	139	28	112	76	12	370
" New Species	2	133	26	105	76	12	354
Species founded on leaves, fruits, etc.	3	139	28	107	76	12	365
" " internal structure				5			5
" occurring elsewhere (identical)	1	6	2	7			16
" allied to previously known species	1	45	8	26	17	1	98
" admitting of comparison	2	51	10	33	17	1	114
" not admitting of comparison	1	88	18	79	59	11	256

I have prepared the foregoing table, showing the principal elements of the Potomac Flora as elaborated by Professor Fontaine and Professor Knowlton, from which it appears that the whole number of species thus far known is 370, consisting of 3 species of Equisetum, 139 ferns, 28 cycads, 112 conifers, 76 dicotyledons, and 12 species whose systematic position is not definitely known. Of this number, 354 are new species, leaving only 16 species which are common to the Potomac and other formations. But in comparing these new species with the other fossil floras of the globe, 98 of them have been found to resemble to a greater or less extent species figured from elsewhere, leaving 256 species, or nearly 69 per cent, which do not sufficiently resemble known forms to suggest any close relationship. It is therefore only the 16 identical and 98 presumably allied species, or considerably less than one-third of the whole flora, that we have to do with in our comparison of species. The forms with which these 114 species are found to possess characters in common are derived from 37 distinct floras, ranging from the summit of the Trias to the base of the Tertiary, but chiefly within Jurassic and Cretaceous strata.

Rhetic.—The formation called Rhetic, which some regard as the base of the Jura and others as uppermost Trias, is the oldest that has yielded forms which are comparable with any found in the Potomac formation. Such forms are found at three, and if we include certain beds in China, at four different localities widely separated from one another, which have been correlated as of Rhetic age. The most interesting of these is that of the Richmond Coal Field in Virginia which Professor Fontaine has himself elaborated, and in which he believes he finds the ancestral types of some half dozen Potomac species,

in four of which the resemblance is close enough to warrant the preservation of the generic name.

A somewhat larger number of species are compared with those of Franconia and Seinstedt in Germany, though here the affinities are less close. Six species are compared with forms from the well known Rhetic beds of Sweden and three with the Jurassic of China where Dr. Newberry found plants identical with those collected by Emmons in North Carolina.

Taking all these Rhetic localities together we find that fourteen Potomac species have important characters in common with Rhetic plants, although none of them are specifically identical.

Lias.—The Rajmahal group of India has generally been referred to the Lias and is the only flora of that age which contains types that reappear in the Potomac beds. Six species are compared in three of which the same genera occur, but two of the remainder either present only an accidental resemblance or there has been a mistake in their generic reference.

Oolite.—Six Oolite beds contain analogous forms to those of the Potomac These are: 1. The Upper Gondwanas of India; 2. That of Cape Boheman, Spitzbergen; 3. Those of eastern Siberia; 4. Those in Russia, worked up by Schmalhausen; 5. Those of Italy monographed by Zigno; and 6, the celebrated Yorkshire Oolites. The Siberian and Yorkshire beds, however, have yielded the greater part of the species allied to Potomac plants. Thirty-one species of Potomac plants have allies in the Oolite flora, but as yet there occur none that are identical.

Upper Jura.—The upper Jurassic deposit at Solenhofen in Bavaria, the Coral beds of Verdun and St. Mihiel in France, and the Kimmeridge strata at Morestel and the Lac d'Armaille, have each yielded forms, especially of the coniferous genus Brachyphyllum, which closely resemble Potomac specimens.

Wealden.—The Wealden of England furnishes two species which also occur in the Potomac formation. These are *Equisetum Lyelli* Mant., and *Sphenopteris Mantelli* Brongn., the latter of which also occurs in the Wealden beds of Germany, first monographed by Dunker. Besides these there occur on the Island of Portland and the Isle of Wight certain Cycadean trunks referred to Cycadeoidea, Bennettites and Mantellia, which are very similar to those found by Tyson in Maryland, called by Professor Fontaine *Tysonia Marylandica.*

A much larger number of identical species are found in the Wealden of Germany. Besides the one already mentioned as common to strata of that age in England and Germany, we have *Pecopteris Browniana* Dunk., *P. Dunkeri* Schimp., *Dioönites Buchianus* Schimp., *Dioönites abietinus* Miquel,

Sphenolepidium Kurrianum Heer, and *S. Sternbergianum* (Dunk.) Heer, in all seven identical species. Nine other Potomac species have allies in the Wealden of Germany.

Four Potomac species are allied to plants found in Japan, in deposits usually regarded as Jurassic, but which may be lower Cretaceous.

Forms of *Pecopteris Whitbiensis* found by Trautschold at Klin near Moscow closely resemble *Cladophlebis falcata* and *C. oblongifolia* of the Potomac flora. Professor Fontaine, following Schenk, regards this deposit as Wealden.

Neocomian.—The principal beds recognized as belonging to this series containing Potomac types, are those of the Valle de Lobos and of Almargem in Portugal, whose flora was elaborated by Heer in 1881. Four of the Wealden species found in the Potomac and already enumerated recur here, leading to the strong suspicion that the Portuguese beds may also be of Wealden age. One of these (*Sphenolepidium Sternbergianum*) is also found in alleged Neocomian strata near Oerlinghausen in Westphalia.

Professor Fontaine's *Taxodium Virginicum* appears to be allied to *T.* (*Glyptostrobus*) *Groenlandicum* of Heer, which occurs in the Kootanie beds of the British Northwest Territory, correlated by the Canadian geologists with the Neocomian, and *Araucarites Virginicus* resembles *Araucaria cretacea* Brongn. from Nogent-le-Rotrou in France, which is thought to be not lower than Cretaceous.

There are therefore four species common to Neocomian and Potomac strata, and seven others which are related more or less closely.

Urgonian.—To this epoch are referred the Kome beds of Greenland, and the Wernsdorf beds, lying chiefly in Austrian Silesia. The rich flora of the former was elaborated by Heer, and it will be remembered that it was here that a single dicotyledonous plant, *Populus primaeva* Heer, was found which, if no mistake was made, was the most ancient plant belonging to that subclass that had been found prior to the opening up of the Fredericksburg beds. This species does not occur in the Potomac flora, but five other Kome species do occur there, viz: *Gleichenia Nordenskiöldi* Heer. (though this is somewhat doubtful), *Sequoia Reichenbachi* (Gein.) Heer, *S. ambigua* Heer, *S. rigida* Heer, and *S. gracilis* Heer. Besides these identical species there are eleven Potomac plants that bear more or less resemblance to those of Kome.

The Wernsdorf beds contain two species found in Potomac strata, one of which, *Dioönites Buchianus* Schimper, does not occur at Kome, and there are four other species of Potomac

plants that have near relatives in that deposit. The Urgonian therefore furnishes six identical and sixteen allied species.

Gault.—The Cretaceous deposit at Cape Staratschin, in Spitzbergen, which has been referred to the Gault, contains two of the species that have been enumerated as occurring in the Kome beds and also in the Potomac formation, and also two other species which resemble Potomac plants.

Cenomanian.—The rich Cretaceous flora of Atane, Greenland, so carefully worked up by Heer and correlated with the Cenomanian of Europe, furnishes six species which have been detected in Potomac strata, but all but three of these, *Pecopteris socialis* Heer, *Aspidium Oerstedi* Heer, and *Sequoia ambigua* Heer, have already been enumerated from the Kome beds through which they extend up into those of Atane. The number of additional species with which there are related Potomac forms amounts to nine, but the relationships are in some cases quite distant.

The Cenomanian of Bohemia and Moravia has 1 identical and 6 allied species, and that of Saxony (Niederschöna) 2 identical and 3 allied, but one of the identical species is the same in both and has a wide range, while the other also occurs in the Wernsdorf beds.

We thus have for the Cenomanian 7 identical and 23 allied species.

Dakota Group.—In the Dakota Group, which should probably also have been classed as Cenomanian, only two plants occur which are also found in the Potomac formation, and both of these are found in other localities, one of them having a very wide range and distribution. The Potomac Dicotyledons are all specifically, and nearly all generically, distinct from those of the Dakota Group, but ten species are compared and may be related to Dakota forms.

Senonian.—Under this designation I have grouped the upper Cretaceous beds of Patoot, Greenland, of the Peace and Pine River district of the British Northwest Territory, of Quedlinburg in the Harz, the Gosau beds of Tyrol, the Westphalian beds, so well worked by Hosius and Von der Marck, and the sands of Aix-la-Chapelle. The same species recur largely in these beds, *Sequoia Reichenbachi* being found in them all. Five species are common to the Potomac formation and one or more to these localities, but all of these are found in older strata. Nine Potomac plants are also compared and perhaps related to Senonian species.

Laramie Group.—Only one species, the widespread *Sequoia Reichenbachi*, is common to the Potomac formation and Laramie group, and no further comparisons are made.

Eocene.—The two comparisons made with Eocene plants, viz: *Araucaria podocarpoides* with *Podocarpus incerta* Ett.

and Gard., and *Rogersia longifolia* with *Glossochlamys transmutans* Ett. and Gard., from the London clays, are too remote to possess any value for the present discussion.

The relations of the Potomac flora to those of other formations may now be summed up in tabular form. The 16 identical and 98 allied species are composed of 53 cryptogams, all but 2 of which are ferns, 9 cycads, 35 conifers, and 17 dicotyledons, and as the lower types are somewhat more prominently represented in the lower formations and the higher in the higher, this relation may perhaps be best shown in the following form.

Geological Formations.	Cryptogams.		Cycads.		Conifers.		Dicotyledons.		Total.	
	Identical.	Allied.	Identical.	Allied.	Identical.	Allied.	Identical	Allied.	Identical.	Allied.
Eocene						1		1		2
Laramie Group					1				1	
Senonian					5	7		2	5	9
Dakota Group	1				1	1		10	2	11
Cenomanian	2	9	1	1	4	5		8	7	23
Gault		1			2	1			2	2
Urgonian	1	7	1	2	4	7			6	16
Neocomian	2	2		1	2	4			4	7
Wealden	4	11	2	1	2	1			8	13
Kimmeridgian		1				3				4
Corallian		1				5				6
Oolite		24		2		5				31
Lias		4		2						6
Rhetic		8		4		2				14

From this exhibit it appears that no Jurassic species occurs in the Potomac formation, although it contains a large number of strongly Jurassic types. The Wealden furnishes the largest number of identical species, the Cenomanian next, and the Urgonian next. Of allied species, although the largest number occurs in the Oolite, the Cenomanian, Urgonian and Wealden, each furnish many. Taking the identical species and considering the Wealden as Cretaceous, the flora would appear to be decidedly Cretaceous, but if this showing is considered in the light the Jurassic types cast upon it, it is difficult to believe it to be higher than Wealden or Neocomian.

Another class of facts still further strengthen this view. Leaving the allied species aside, and considering only the identical ones, we see that a large number of these recur in most of the members of the Cretaceous. As already stated, there are only 16 identical species, while the sum of those in all the formations as here presented would be 35. This results from their repetition. Three species are confined to the Wealdne,

viz: *Equisetum Lyelli* Mant., *Pecopteris Browniana* Dunk., and *Dioönites abietinus* Miquel, which Prof. Fontaine treats as a variety of *Dioönites Buchianus* Schimp. Only one species is confined to the Urgonian, viz: *Sequoia gracilis* Heer, and only two to the Cenomanian, viz: *Pecopteris socialis* Heer and *Aspidium Oerstedi* Heer, both from the Atane beds of Greenland. The remaining ten identical species range through more than one series, most of them through several. Two species are found in the Wealden and Neocomian, viz: *Sphenopteris Mantelli* Brongn., and *Pecopteris Dunkeri* Schimp, which Prof. Fontaine regards as a true Aspidium. One Wealden species, *Dioönites Buchianus* Schimp, is found in both the Urgonian and the Cenomanian, and two, *Sphenolepidium Kurrianum* Heer, and *S. Sternbergianum* (Dunk.) Heer, are found in the Wealden, Neocomian and Senonian. One species, *Gleichenia Nordenskiöldi* Heer, occurs only in the Urgonian and the Dakota Group; another, *Sequoia ambigua* Heer, only in the Urgonian and Cenomanian of Greenland. *Sequoia rigida* Heer, occurs in the Urgonian, Gault, Cenomanian and Senonian, while *Sequoia Reichenbachi* (Gein.) Heer, runs through the Urgonian, Gault, Cenomanian, Dakota Group, Senonian, and is even found in the Laramie Group. The only species not already mentioned is *Sequoia subulata* Heer, which is found only in the Cenomanian and Senonian of Greenland.

These results can be shown in tabular form, and, if the species be arranged in ascending geological order they will stand as follows:

Species common to the Potomac and other Formations.	Wealden.	Neocomian.	Urgonian.	Gault.	Cenomanian.	Dakota Group.	Senonian.	Laramie.
Equisetum Lyelli *Mant.*	1							
Pecopteris Browniana *Dunk.*	1							
Dioonites abietinus *Miquel.*	1							
Sphenopteris Mantelli *Brongn.*	1	1						
Pecopteris Dunkeri *Schimp.*	1	1						
Sphenolepidium Kurrianum *Heer.*	1	1					1	
Sphenolepidium Sternbergianum (Dunk.) *Hr.*	1	1					1	
Dioönites Buchianus *Schimp.*	1		1		1			
Sequoia gracilis *Heer.*			1					
Sequoia ambigua *Heer.*			1		1			
Sequoia rigida *Heer.*			1	1	1		1	
Sequoia Reichenbachi (Gein.) *Heer.*			1	1	1	1	1	1
Gleichenia Nordenskioldi *Heer.*			1			1		
Pecopteris socialis *Heer.*					1			
Aspidium Oerstedi *Heer.*					1			
Sequoia subulata *Heer.*					1		1	

This presentation brings out in a clear light the value of these species in determining the age of the Potomac formation. Just half of them are found in the Wealden, and all but three occur below the Cenomanian.

Two problems of considerable importance remain to be considered, viz: First, how much weight to give to the large number of Jurassic types as indicating a Jurassic age for the formation, and secondly, how much to give to the Dicotyledons as pointing to a middle Cretaceous age.

As regards the first, we find that eight ferns, four cycads, and two conifers have representatives in the Rhetic, which some regard as uppermost Trias; four ferns and two cycads in the Trias, or lower Jura; 24 ferns, two cycads and five conifers in the Oolite, and two ferns and eight conifers in the upper Jura (Corallian and Kimmeridgian). These species, of course, overlap and recur in the different members in the same way as the identical species were shown to do, but nevertheless they present a strong case. For example, 27 out of 46 cryptogams, 4 out of 7 cycads, and 11 out of 28 conifers have allies in the Jurassic; that is, over half of the species, exclusive of Dicotyledons, that admit of any comparison at all, show affinities with Jurassic and Rhetic forms. And even this does not show the full force of the evidence of this class, since there are many genera, both of ferns and conifers, which predominate in the Oolite and in the Rhetic, and are either wholly absent or very rare in the Cretaceous, which yet have numerous representatives in the Potomac, and therefore all the species of these genera, whether they have closely related species in the Potomac or not, bear directly upon this point.

Thus Cladophlebis is represented by 22 species, only 14 of which are related to forms found elsewhere. The genus is chiefly Jurassic.

Thinnfeldia is a large Jurassic genus ranging from the middle Trias, but found also in the Cretaceous of Spitzbergen and Greenland. The Potomac species are, however, Rhetic in type.

Angiopteridium has no Cretaceous forms, and although there are two alleged Miocene species, the nine Potomac forms are strong lower Jurassic and Rhetic types.

Thyrsopteris, leaving Stur's Culm species out of the account, ranges from the Permian to the Malm of Portugal, held to be brackish-water Jurassic, called Wealden by Heer, but the genus is chiefly Oolitic. It is the most abundant fern in the Potomac formation, numbering forty species, only eight of which admit of specific comparison with forms previously known. Yet all of these forty species speak for the Jurassic age of the deposits containing them.

Platypterigium has been heretofore found only in the Lias of India. Its occurrence in the Potomac, therefore, in so far favors the same conclusion.

Brachyphyllum is a well known upper Jurassic type, but is found as low as the Muschelkalk and as high as the Neocomian. An occasional species in the Cretaceous would not be considered strange, but we find stems, leaves and fruits referable to five species in the Potomac formation, all of which are comparable to those found in the Corallian and Kimmeridgian deposits of France and of Solenhofen in Bavaria.

Other cases might be considered, but these will suffice to show how strong a Jurassic facies the Potomac flora possesses.

It remains to consider the second question, as to the true significance of the Dicotyledons. Their presence is supposed to indicate a later age than that denoted by the other groups of plants. It was long supposed that the upper Quader beds of Blankenburg contained the earliest remains of plants of this class, but they were at length found in the considerably older strata of Niederschöna in Saxony. Since then their occurrence in strata of about the same age in Bohemia and Moravia was made known, and it is the practice to treat the so-called upper Cretaceous of Greenland, the Dakota Group of Kansas and Nebraska, and the Raritan clays of New Jersey as homotaxially equivalent to these Continental deposits.

With but a single exception no dicotyledonous plants had been found lower than this horizon prior to the discovery of the Fredericksburg bed. This exception was the occurrence among the collections from Kome in Greenland, a deposit whose animal remains are said to fix its age as Urgonian, of a single dicotyledonous species, the *Populus primæva* of Heer, all the other plant remains from that deposit belonging to the lower types. Although this discovery has not been confirmed by subsequent research, and therefore remains subject to the doubt whether the collections may not have become mixed with those from higher beds made and sent at about the same time, still there is nothing antecedently improbable in it, and it may pass unquestioned. It does not, however, invalidate the general proposition that up to this time the Cenomanian has furnished the most ancient forms of dicotyledonous plants.

This cannot now be said, and we have in the Potomac formation a still earlier date at which to fix the observed origin of the type of vegetable life which is now the predominant one upon the globe. What then does this dicotyledonous element in the Potomac flora prove as to the age of that formation? Can we argue from its analogy with other Cretaceous floras? In doing so great caution is required. As compared with these the Potomac flora is wholly anomalous in this respect. In all the

others, with the sole exception already mentioned, instead of those plants coming in gradually, as they would be expected to do if the formation represented an age at which their development was inchoate, and instead of presenting rudimentary, transition, and archaic types of that subclass, as such early deposits would naturally do, we find them to be the prevailing, sometimes, as in the Dakota Group, almost the only form of plant life, and we also find them fully developed, and even when most unlike our modern vegetation, still exhibiting all the characters of highly organized plants of their rank. In the Potomac formation, on the contrary, we find the Dicotyledons behaving precisely as they ought to behave in a formation that represents an age close down to that at which this form of life first made its appearance in the geologic history of the globe. We find them to constitute the great rarities of the flora, absent from many of the most productive beds, scarce at all places in comparison with the lower types of vegetation, strange and peculiar in character, so vague and ill-defined as in some cases to cause doubts as to whether they really belong to this group of plants, possessing features that recall the ferns, Cycads, Conifers, and even the Monocotyledons, and containing comprehensive types prophetic of many of the now fully developed families of Dicotyledons. They therefore form just such a homogeneous and undifferentiated group of plants, combining in a scarcely distinguishable way all the elements of the later dicotyledonous flora, as we should expect to find existing during the early history of this type of vegetation. They are therefore not to be regarded as anomalous but as normal, and the anomaly, if any there be, exists in Cenomanian floras, where this type occurs in such a predominant and highly developed form.

In view of these facts I cannot accept the conclusion that the dicotyledonous element of the Potomac flora argues a more recent age than that denoted by the other types. On the contrary, the immense difference between this and the Cenomanian floras clearly indicates that a vast period must have been required to produce so great a development.

On numerous occasions, dating as far back as 1878,* I have expressed the opinion that the Dicotyledons could not have had their origin later than the middle Jura, and it will not sur-

* American Naturalist, vol. xii, June, 1878, p. 378; November, 1878, p. 734. In a lecture delivered February 24, 1883, at the National Museum on Plant Life of the Globe, past and present (see Science, vol. i, May 4, 1883, p. 358). American Journal of Science, third series, vol. xxvii, April, 1884, p. 302. Proc. A. A. A. S., vol. xxxiii. Philadelphia Meeting, September, 1884, p. 497. Botanical Gazette, vol. ix, Indianapolis, October and November, 1884, p. 174. Fifth Annual Report U. S. Geological Survey, 1883–84, Washington, 1885, diagram, pl. lviii, facing p. 452.

prise me if the final verdict of science shall place the Potomac formation, at least the lower member in which the plants occur, within that geologic system. While the remaining types point strongly in this direction, I do not regard the Dicotyledons as at all negativing, but even more strongly suggesting this view.

Still it may be admitted that according to the ordinary modes of arguing from similar statistics, the sum of all the facts here presented would make the Potomac, considered from the point of view of the flora alone, homotaxially equivalent to the Wealden of England and North Germany, now usually included in the Cretaceous system. If the vertebrate remains are Jurassic and the flora Cretaceous we only have here another confirmation of a law exemplified in so many other American deposits, that, taking European faunas and their correlated floras as the standard of comparison, the plant life of this country is in advance of the animal life. This law has been chiefly observed in our Laramie and Tertiary deposits, but is now known to apply even to Carboniferous and Devonian floras. It is therefore to be expected that we shall find it to prevail during the Mesozoic era. If, therefore, it be finally settled that the fauna of the Potomac series is homotaxially Jurassic, and we take our starting point from Old World geology, there will be no more objection to regarding the Potomac flora as Jurassic than there is now in contemplating the Laramie flora as Cretaceous. In fact, so far as the character of the flora is concerned there is much less difficulty in the case of the Potomac than in that of the Laramie, since I have shown the Potomac flora, viewed in all its bearings, cannot be said positively to negative the reference of the formation to the Jurassic upon the evidence of the plants alone.

I do not, however, desire to be understood as arguing for the Jurassic age of the Potomac formation. The most that it is intended to claim is that, if the stratigraphical relations and the animal remains shall finally require its reference to the Jurassic, the plants do not present any serious obstacle to such reference.

ART. XIV.—*Experiments on the Effect of Magnetic Force on the Equipotential lines of an Electric Current;* by E. H. HALL, Instructor in Physics at Harvard College.

THE experiments of which the following article will give some results have been made in the Jefferson Physical Laboratory of Harvard College at occasional intervals during a period of more than three years. Some of the results have been an-

ticipated by other investigators. I desire to thank the trustees of the Bache Fund for a liberal appropriation which has been of great assistance in the prosecution of the work.

About four years ago, Mr. Shelford Bidwell published what at first appeared to be an explanation of the so-called Hall effect as being due to a thermo electric current set up between strained and unstrained portions of the same piece of metal, an effect which Thomson had discovered and which was well known. The theory thus advanced did not stand the test of examination, but it appeared from a table which Mr. Bidwell gave that, at least, the direction of the effect which magnetic force exerts upon the equipotential lines of an electric current in any given metal could be inferred from the sign of the effect produced by stress upon the thermo-electric property of the metal. Messrs. Coggeshall and W. A. Stone, of the class of 1886 in Harvard College, working with my coöperation, confirmed Mr. Bidwell's table in the case of copper, iron and zinc, but found exceptions to it in French cold-rolled steel and aluminium. No other metals were examined by them. In all cases both effects were tested. A note stating most of these facts was published in *Science*, March 27, 1885.

In this Journal for February, 1885, commenting upon the alleged reversal of the "Hall effect," which Mr. Bidwell had found in a strip of gold having two narrow longitudinal slits nearly meeting, I ventured to predict the results of experiments to be made for testing the effect of magnetic force upon the equipotential lines of an electric current in strips of metal, the forms of which may be called variations upon the type used by Mr. Bidwell.

For these experiments I have used untempered "French cold-rolled steel." This is described by the dealer who furnishes it as "celebrated for its toughness and superior quality for striking up in die or presswork." This steel is procured in the form of ribbons about 8^{cm} wide. From such a ribbon transverse strips were cut about 21^{mm} wide and in length equal to the width of the ribbon. They were all about $\frac{1}{10}^{mm}$ in thickness. Along the middle of these strips longitudinal slits were cut, in some strips one, and in others two in line separated by a certain space. (For illustrative figures see the article mentioned above.) As all the results obtained with these strips were such as might be expected from the considerations given in the article alluded to, and as these considerations have not, so far as I am aware, become the subject of criticism, it seems unnecessary at present to describe either the apparatus or results in detail. The experiments were made in February, 1885.

Long Strip and Short Strip.—At the Philadelphia meeting of the American Association in 1884 I gave reasons for think-

ing that the transverse effect would prove to be less marked near the end than in the middle of a metal strip. Similar reasons led me to suppose that the effect would, *cet. par.*, be less in a short strip, No. 16, than in a long strip, No. 15, both being of F. C. R. steel. Strip No. 15 was like those already described but without any slit: Strip No. 16 was cut from the middle of a strip like 15 and was of about the same width, but only $1{\cdot}1^{cm}$ or $1{\cdot}2^{cm}$ long. Fearing that soldering connections to the ends of so short a strip as No. 16 would change the character of the strip throughout, I used no solder with Nos. 15 and 16, but made connection with their ends by means of strips of lead pressed firmly down upon them by means of stout clamps. For No. 16 each of the lead strips was made about 4^{cm} long and as wide as the steel in order to give the main current, coming in from the connecting wires, opportunity to spread and become parallel to the edges of the strip before entering the steel. The part of No. 16 not *covered* by the lead was about 5^{mm} long. Whether the space not *touched* by the lead was longer, cannot be ascertained, but the extreme length possible was, as the dimensions already given show, about $1{\cdot}1^{cm}$. Lead was used for making connections partly because its softness made a good contact probable and partly because, lead showing very little or no transverse action of the sort under examination, its use would practically limit this transverse action to the steel strip.

The transverse connections were made, as with the other steel strips mentioned in this article thus far, by means of two stiff German-silver springs, each touching the steel at one point.

The considerations which led to the experiments with 15 and 16 were nearly as follows: The transverse action, whatever may be its explanation, makes the equipotential lines run obliquely instead of straight across the strip in which it occurs. If such a strip were short and were joined at each end to another strip in which the same action does not occur, the direction of the equipotential lines in each strip near the junction should be affected by the proximity of the other strip, so that lines in the *inert* strip would not run perfectly straight across and lines in the *active* strip would run less obliquely than they otherwise would. If a strip were short, like No. 16, this modification in the direction of the lines might be apparent throughout its whole length, so that the transverse action in a short strip might appear less powerful than in a long strip.*

May 23, 1885, Nos. 15 and 16 were tested, No. 16 first, then No. 15, finally No. 16 again. These tests were by no means accurate, but they left no doubt that the apparent transverse

* See also, upon this point, Ettingshausen and Nernst in the *Beiblätter zu den Annalen der Phys. u. Chem.*, Band xi, Stück. 5.

effect was considerably smaller in the short strip than in the long one, the difference amounting apparently to about 20 per cent.

Strips differing in Cross-Section.

Every experiment which bears upon the relation between the transverse action in a strip and the magnetic condition of the strip is of interest. Strips of any strongly magnetic metal under the conditions of these experiments become the more strongly magnetized the greater the ratio of the thickness to the width, but with the non magnetic, or weakly magnetic, metals, no such variation is observable. It is, then, important to ascertain what relation this ratio of thickness to width has upon the transverse action in magnetic and non-magnetic metals.

Crosses of Norway iron, of cobalt, of nickel, of silver and of bismuth have been tested with this object in view

Silver.—From a half-dollar coin (silver 9 parts, copper 1 part) two crosses were made, the dimensions of which were approximately as follows.

	Width.			
	Main part.	Arms.	Thickness.	Length.
	mm.	mm.	mm.	mm.
No. 1	9·5	1·5	1·02	25
No. 2	0·5	0·5	1·00	23

The smallness of visible effect in these thick pieces of silver made the comparison tedious. The results obtained were nearly as follows, correction being made for the difference in thickness:

Date.	Magnetic field.	Effect in No. 1.	Effect in No. 2.
Feb. 8 or 9, 1886	9,500	100	93
Feb. 10, 1886	10,000	100	100·9
July 23, 1886	10,000	100	98·7

The strength of field is here given roughly in absolute c. g. s. units. The observations of the first day were less accurate and therefore are entitled to less weight than those of Feb. 10th and July 23d. It appears safe to conclude that in the case of silver the width of the cross has no considerable influence upon the transverse effect. The absolute magnitude of the R. P.* in this metal appeared to be about 750×10^{-6}.

$$* \text{ R. P.} = \frac{E \times T}{M \times C},$$

where E represents the total transverse electromotive force in c. g. s. units.
M represents the intensity of the magnetic field in c. g. s. units.
C represents the strength of the direct current in c. g. s. units.
T represents the thickness of the cross in cm.

In previous papers I have not given the R. P's in absolute units, having neglected, as Professor Boltzmann has surmised (*Anzeig. d. Kais Akad. in Wien*, 1886, *Nr. X*), to change a resistance from ohms to absolute c. g. s. units. To turn the R. P's given in my article of February, 1885, into absolute c. g. s. units, it is necessary to multiply them by 10^9.

Norway iron.—Eight crosses of iron were used in such tests. Nos. 1, 3, 5 and 7 are broad; Nos. 2, 4, 6 and 8 are narrow. Nos. 1–4 were cut from one bar of ordinary Norway iron such as blacksmiths use. Nos. 5–8 were cut from another bar of the same kind.

Of these bars the ends, which had possibly been heated and hammered more than the other portions, were avoided in cutting out the crosses. The dimensions of the crosses, as given below are only roughly correct.

	Width.		Thickness.	Length.	
	Main part. [near arms.]	Arms. [near main part]	Main part. [near arms.]	Main part.	Arms. [each.]
No. 1	$7{\cdot}0^{mm}$	$2{\cdot}0^{mm}$	$2{\cdot}20^{mm}$	40^{mm}	6^{mm}
2	0·5	0·5	2·30	42	9
3	9·5	2·0	2·86	43	4
4	0·5	0·5	2·85	42	7
5	8·0	2·0	0·50	31	4
6	0·5	0·5	0·48	30	9
7	9·0	2·0	3·00	38	5
8	0·5	0·5	3·00	33	9

Nos. 1 and 2 were compared June 18th and 19th, 1885. The strength of magnetic field used is not recorded. The comparison, which was very rough, gave

$$\frac{\text{R. P. in narrow cross}}{\text{R. P. in broad cross}}=1{\cdot}5.$$

Nos. 3 and 4 were compared in August, 1885, in a magnetic field the intensity of which was about 8000 or 9000 (c. g. s.). This test, which also was rough, gave

$$\frac{\text{R. P. in narrow cross}}{\text{R. P. in broad cross}}=1{\cdot}3.$$

Nos. 5–8 were tested Dec. 31st, 1885, and Jan. 1st, 1886. The order of trial on Dec. 31st was Nos. 7, 8, 6, 5, 5, 6, 8, 7. The purpose of this arrangement was to eliminate, so far as practicable, from the result of the trial error arising from changes in certain factors of the test during the progress of the experiment, such as a possible variation in the sensitiveness of the astatic galvanometer used to measure the transverse current or a gradual weakening of the magnetic field. An occasional observation of the time of vibration of the needle in the astatic galvanometer showed that no great change was occurring in the sensitiveness of this instrument. The weakening of the magnetic field in the course of the day was probably less than 10 per cent. By combining the two observations made with each cross four results are obtained which should

be nearly free from error due to such changes. These results are given below in numbers which are merely relative, the smallest being made 100.

Strip.		R. P. on arbitrary scale.	Mean.
No. 5		100+	100
5		100−	
6		153·4	154·3
6		155·3	
7	(see below)	131	142·5
7		154	
8		318·3	323·2
8		328·1	

The intensity of the magnetic field in these experiments was probably between 5500 and 6000 (c. g. s.). A rough test indicated that the R. P. of No. 5 was about 9000×10^{-6}.

The two tests with No. 5, which came close together in time agree best. Next in agreement come the tests with No. 6, next those with No. 8, and finally the two trials of No. 7, which came farthest apart in time, are widely divergent in results. The divergence here is so great that a new comparison of Nos. 7 and 8 was made the next day, the magnetic field being kept for this purpose about the same as on Dec. 31st, although later in the day a stronger field was used. This comparison gave

$$\frac{\text{R. P. of No. 8}}{\text{R. P. of No. 7}} = \frac{1075}{506}, \text{ or } \frac{323}{152}.$$

The mean of this result and that of Dec. 31st gives

$$\frac{\text{R. P. of No. 8}}{\text{R. P. of No. 7}} = \frac{323}{147}$$

in a magnetic field of about 6000 (c. g. s.).

The influence of the shape of the specimen examined is quite evident in all the experiments upon Norway iron thus far described. The most important part of a cross is, no doubt, the region made up of the bases of the arms and the portion of the main strip between and near the arms. This region may be called the *effective portion* of the cross. All these experiments upon Norway iron show that a cross of this metal in which the effective portion has the ratio *thickness÷width* comparatively large, shows a comparatively large R. P. This fact is brought out in a particularly interesting manner by the experiments of Dec. 31st and Jan. 1st, just described. From the dimensions already given it is evident that the ratio *thickness÷width*, is least in No. 5 and greatest in No. 8. In No. 7 it is greater than in No. 5 and in No. 6 greater than in No. 7. Accordingly we are prepared to find, and do find, that the

R. P. is smallest in No. 5, larger in No. 7, still larger in No. 6, and largest in No. 8.*

In the test already described the R. P. of No. 8 was, in fact, three times as great as that of No. 5, and as the latter was quite strongly magnetized, it seemed not unlikely that No. 8 was in a condition approaching what is called the state of *magnetic saturation.* If this were the case, No. 8 probably would, when placed in a stronger magnetic field than that used Dec. 31st, suffer a diminution of its R. P., while Nos. 5, 6 and 7 should show less or no diminution of this sort under similar circumstances. Accordingly on Jan. 1st, 48 cells, 6 abreast, were used in the magnet circuit, the number used the day before having been 30, 6 abreast. This brought the magnetic field up to about 7000. The four crosses were then tested essentially as on Dec. 21st, the order being as before, Nos. 7, 8, 6, 5, 5, 6, 8, 7. The numbers given by this trial, like those obtained Dec. 31st, are only comparative. They do not represent the absolute values of the R. P's, and for convenience they have been reduced to such a scale as to give No. 5 the same representative number that it had in the results of Dec. 31st.

Results of Jan. 1st, 1886, with magnetic field about 7100 (c. g. s.) :—

	R. P. on arbitrary scale.	Mean.
No. 5	101 99	100
6	152 154	153
7	144 148	146
8	260 270	265

On comparing these figures with those given above, it appears that the relative standing of Nos. 5, 6 and 7 was affected very slightly, by going from the weaker to the stronger magnetic field, but No. 8 shows a great falling off. So great, in fact, was this charge in No. 8, that the observations made at this time did not clearly show whether the magnetic field of about 7100 produced upon the equipotential lines of the electric current in this cross an effect greater or less than that produced by a field of less than 6000. But experiments made Aug. 3d, 1886, with the same cross indicate that a field of 10,500 produces an effect one or two per cent greater than a field of 8000.

* The results obtained with No. 7 were so variable on these two days that its place among the others cannot be assigned with confidence. Later experiments make its R. P. relatively larger.

On Jan. 7th, 1888, Nos. 5, 6 and 8, were tested in a field of about 3800. The relative sizes of the R. P's in this field are represented by the following numbers, no one of which is probably in error more than 5 per cent of itself:—

For No.	5	100
	6	158
	8	436

It will be seen that the relative standing of Nos. 5 and 6 is not seriously changed, although No. 6 gains a little as was to be expected. No. 8 makes a large gain.

If in the results of these tests, we look for something more than the general influence of shape upon transverse effect, and inquire whether the relative intensity of magnetization in each cross corresponds accurately to the relative magnitude of the R. P. therein, we find it impossible to determine exactly the intensity of magnetization in the several crosses, as they do not closely resemble any of the forms for which accurate calculation has been made. It may be worth while, however, to note what are the results of calculation in the case of certain typical forms.

We find in Maxwell, Art. 400, that in general

$$B = (1+4\pi\kappa)\ H \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where B is the intensity of "magnetic induction through the the body," H the "magnetic force" ("polar definition") within the body and κ is Neumann's coefficient, a quantity which Maxwell supposed to be about 30 for soft iron, but which Rowland has found to be at times much greater than that in Norway iron.

Letting H represent the magnetic force directly due to the poles of the electro-magnet, we find from Maxwell, Art. 438, that in a cylinder placed between these poles so as to become magnetized transversely this relation holds

$$H = \mathrm{H} - 2\pi k H, \text{ or } H = \frac{\mathrm{H}}{1+2\pi\kappa}. \quad . \quad . \quad . \quad . \quad (2)$$

From (1) and (2) we find

$$B = \mathrm{H}\frac{1+4\pi\kappa}{1+2\pi\kappa}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

For ordinary values of κ we find approximately for this cylinder

$$B = 2\mathrm{H}.$$

In case of a sphere we find

$$B = \text{approximately } 3\ \mathrm{H}.$$

In a thin disk magnetized longitudinally, i. e. in a direction normal to the faces, the law is B=H. The *effective portion* of cross No. 5 is fairly well represented by such a disk, and we shall assume that with this cross B was nearly equal to H.

In case of a disk magnetized *transversely*, i. e. parallel to its faces, the diameter being to the length as 6 to 1,

$$B = \text{approximately } 8 \text{ H}.$$

As the thickness of cross No. 8 was about 3^{mm} and as the width of the main part was in general about $0{\cdot}5^{mm}$, it might be thought that this cross presented a case similar to this latter disk, but it must be remembered that the *effective portion* included the bases of the arms. It is likely, too, that both the main part and the arms were somewhat more than $0{\cdot}5^{mm}$ wide at the junction. The case lies, probably, between that of the disk magnetized transversely and that of the sphere, but nearer that of the sphere. It seems not unlikely then, that in a field of moderate strength, such as would not bring either cross near to the condition of "saturation," No 8 might become four or five times as strongly magnetized as No. 5. It will be remembered that in the experiments of Jan. 7th, with a field of moderate intensity the R. P. of No. 8 was about $4\frac{1}{3}$ times as great as that of No. 5.

The primary object of these experiments was to obtain new evidence bearing upon the question whether the transverse effect studied is due to a distortion of the cross as a whole under the combined action of the ordinary "pondero-motive force," as Mr. Bidwell and, doubtless, others have supposed, or to some internal interaction, which for want of a better term may be called *molecular*, of the magnetic and electric states of the conductor. The results obtained lend no support to the former of these two hypotheses, but they are in complete accord with the latter, which must, I think, be regarded as established.

Wishing to study still further the connection between the internal magnetic condition of iron and the transverse effect in it, I have made recently a series of experiments comparing the behavior of the two broad crosses Nos. 5 and 7. Instead of depending here upon a calculation of the ratio of the magnetic inductions in the two, I have tried to measure this roughly by a method which I will describe somewhat fully, as I shall probably make use of it in future experiments. A loop of thin well-covered wire (the diameter to outside of covering being about $0{\cdot}25^{mm}$) was placed flat upon each of these crosses between the arms, was pressed well down and secured in place and shape with the usual cement of beeswax and rosin. Each of these loops was somewhat elliptical in shape, that on No. 5 being about $7{\cdot}4^{mm}$ wide and $12{\cdot}4^{mm}$ long, and the one on No. 7

about 8^{mm} wide and 12^{mm} long. In each case the shortest diameter reached nearly from arm to arm. Care was taken to prevent either loop from overhanging the edge of the cross at any point. The loops were made as equal circles by winding them upon a cylinder about 1^{cm} in diameter. They must have had nearly equal areas in their final forms. After somewhat careful measurements the final area of each was estimated at 0·78 sq. cm. This estimate may be wrong by several per cent. for either or both loops.

The plan was to put in turn Nos. 5 and 7 between the poles of the electromagnet and compare, by means of a ballistic galvanometer, the induction currents produced in the loops by suddenly reversing the direction of the magnetic field. It is believed that the ratio of these two induction currents does not differ many per cent from the ratio which the intensity of magnetic induction through the effective portion of one cross bears to that through the effective portion of the other cross.

Comparisons were also made between the induction currents obtained with each loop and those obtained with a coil of four circular turns having a total area about 5·24 sq. cm., this latter coil being the one used to determine the strength of the field when no magnetic metal was between the poles. This coil will be called the *test-coil.* Its ordinary use was not to remain between the poles and give an induction-current upon reversal of the magnet-current, but to be withdrawn suddenly from the field while the magnet remained in full force. This latter use is of course the better one when it can be employed, for it cannot always be assumed that the visible induction effect obtained by reversal will indicate the true change of strength of the field. As this particular matter had to be investigated with some care, I will give the results, although the following table does not attempt great accuracy.

M = intensity of field in c. g. s. units.
d = swing of needle on pulling test-coil out of field.
D = swing of needle on reversing magnet current, test-coil remaining between poles.

M	d	$2 \times d$	D
2300	0°·644	1°·29	1°·16
4800	1·35	2·70	2·43
8900	2·52	5·04	4·87
8100	2·32	4·64	4·38
8500	2·43	4·86	4·60
8700	2·51	5·02	4·83
9200	2·61	5·22	5·13
9200	2·64	5·28	5·20
9250	2·62	5·24	5·14
9700	2·82	5·64	5·54

The first three of these comparisons were carefully made; the others less carefully. In the second the electro-magnet was worked by a battery current. In all the others the current came from a Gramme dynamo. The coil was always withdrawn from the field very briskly on the end of a lever which carried it three or four feet away from the magnet. The reversal was effected by means of a mercury commutator, which was worked by pulling a string and probably turned in a quarter of a second or less. The time of a single swing of the ballistic needle from one elongation to the next was small, not much more than three seconds. The discrepancy between the results of the two methods when comparatively weak fields are used is very great, about 10 per cent. The difference diminishes as stronger and stronger fields are used, and in fields above 9000 appears to be not greater than 2 per cent. Direct comparisons of the two methods were not made in fields much stronger than those given in the table. Indirect comparisons made in a field about 12,000 and in another about 16,000 indicate that the difference continues to decrease as the field increases in strength.

It has been already stated, that the loops on the iron crosses 5 and 7 gave their induction currents by remaining between the poles when the magnet current was reversed. The indications which they gave were therefore subject to a correction in order to make them comparable with those given by the test-coil upon sudden withdrawal from the magnetic field. In the results to be given this correction will be applied in accordance with the indications of the table above. It will be assumed that the proper correction in the strongest fields used is 1 per cent.

The main object of the whole series of experiments being to test the relation between the magnetic induction through the crosses and the transverse effect in them, it was desirable to get the induction current from the loop as nearly as possible simultaneously with the measurement of the transverse current from the arms of the cross. This latter current was measured by a series of readings of an astatic galvanometer, the magnet current being reversed after each reading. At every such reversal, the swing of the ballistic needle due to the induction current from the loop of wire was noted, so that the two series of observations, one upon the transverse effect, the other upon the induction, were carried on at the same time. To avoid error due to direct action* of the electromagnet upon the ballistic and the astatic galvanometers, or to induction in parts of the ballistic galvanometer circuit which

* When the magnet was strongest its direct action upon the astatic galvanometer about 140 feet distant was very important.

were not intended to be subject to such induction, a complete determination with any particular strength of magnetic field required two sets of observations, one made with the cross facing east (the axis of the magnet being nearly east and west), the other made with the cross facing west, all electrical connections being the same throughout the two sets and the condition of the ballistic and the astatic galvanometers remaining, as nearly as practicable, unchanged.

When magnet currents of moderate strength, *e. g.*, 7 or 8 Ampères, were used, two complementary sets were usually made with an interval of not more than 5 or 10 minutes between them, and in such cases the strength of the field was not measured by means of the *test-coil* until the observations with the cross were finished. When the strongest currents were used the magnet became heated rapidly, and thermo-electric effects in the astatic galvanometer circuit soon began to show. In these cases three observations of the astatic galvanometer, right, left, right, or left, right, left, as the case might be, the readings being 1½ minutes apart, were all that could profitably be made on the transverse current. The strength of field was then taken with the test-coil, but by the time this had been done, the magnet had become so hot that the complementary set of observations with the cross faced about could not be made until several hours had passed. When the second set was made the strength of the field was measured again. The magnet current was closely watched by means of an ammeter. This made possible certain corrections and reductions required by the fact that this current and hence the magnetic field could not be kept perfectly constant. It appeared that when the currents were strongest it required about 4 per cent increase in current to produce an increase of 1 per cent in the strength of field. A field of 8000 was increased about 0·6 per cent by an increase of 1 per cent in the strength of the current. A Gramme dynamo supplied the current.

The temperature of the crosses during the experiments is a matter of some doubt. The poles of the magnet have been about 7^{mm} apart in all observations with crosses 5 and 7, since June 1, 1888. No. 7, with the glass upon which it is mounted and the wax in which it is imbedded, makes a mass which nearly fills the space between the poles. No. 5, with its mounting, is considerably thinner. Neither *cross* could possibly come into actual contact with the poles. A few turns of coarse thread were wound around the plates to prevent or impair contact between the glass and the pole and so to impede the flow of heat from pole to cross. The crosses, even with the electric current which each was transmitting, prob-

ably became heated much more slowly than a thermometer which was kept in the bore of the electromagnet. This thermometer rose usually about 5° Centigrade during one set of observations on the transverse current when the strongest magnetic fields were used. If it be assumed that each of the crosses rose in temperature one-half as fast as this thermometer, the conclusion is that the mean temperature of the cross during such a set of observations was not more than one or two centigrade degrees above its temperature at the beginning. This initial temperature was probably known within one or two degrees usually. According to experiments with other specimens of iron and steel,* a change of two degrees in temperature should cause a change of about 1 per cent in the transverse effect in the crosses It is improbable that our conclusions will be seriously affected by the uncertainty as to temperature.

The sensitiveness of the astatic galvanometer was another variable. This was determined three times in connection with this series of experiments by passing a known current through the galvanometer and noting the deflection produced.

The results found were:

	Sensitiveness.
June 4th	100
June 13th	101·4
June 20th	102·6

In the meantime the galvanometer was not touched, so far as I am aware, by anyone but myself and I made no intentional changes in its condition. In making reductions it will be assumed that its change of sensitiveness was uniform from one date to the next. This may leave room for an error of 1 or 2 per cent at some points.

Rough observations of the temperature of the astatic galvanometer circuit were made in order to correct for changes of resistance in this circuit.

A rough preliminary series of experiments was made, beginning with fields of moderate strength and proceeding to stronger and stronger ones, but the troublesome character of the investigation and the pressure of other work have made it necessary to limit the more careful and thorough study to the very strongest fields and to those of medium strength. Even with this limitation the results reached are not in all respects harmonious and satisfactory. The data are given below in some detail in order to show the scope of the corrections and reductions which have been made.

In the tables below—

* This Journal, Feb., 1885.

A = mean reading of ammeter during observations on transverse current. These readings may for our purpose be considered as giving the strength of the magnet current in amperes. This probably understates the current somewhat.

A′ = same during measurement of intensity of magnetic field by means of test-coil.

R = change of reading on scale of ballistic galvanometer produced by induction current from loop on cross. The number of such divisions corresponding to 1° of actual deflection is about 3·6.

M. F. = same produced by induction current from test-coil on being pulled out from magnetic field. These readings reduced to correspond with E. I. at 7.6 and then multiplied by 1000 give approximately the intensity of the magnetic field in absolute, c. g. s. units.

E. I. = same produced by earth inductor in circuit with test-coil and loop on cross.

D = movement from extreme to extreme of spot of light on scale of astatic galvanometer used to measure transverse current from cross. 1° actual deflection = about 3·6 divisions on this scale.

θ = reading of tangent galvanometer measuring direct current through cross. Reduction factor of this galvanometer = about 0·3. Hence direct current = about 2 amperes.

t = temperature of astatic galvanometer circuit.

t' = temperature of cross.

No. 5.

	A	R	D	θ	E. I.	M. F.	A′	t	t'
June 4, 1888.*	24·75	5·05	9·255	35° 46′	7·58	16·47	23·75	27	30
June 5.	26·30	4·65	8·770	36° 37′	7·56	16·83	25·50	27	22
Mean.	25·5	4·85	9·01	36° 12′	7·57	16·65	24·6	27	26
June 8.	24·4	4·96	8·71	36° 23′	7·70	16·27	23·2	29	20
June 8.	25·1	4·93	9·30	36° 28′	7·70	16·27	24·0	29½	28
Mean.	24·8	4·95	9·01	36° 26′	7·70	16·27	23·6	29	24

Reducing the two means to uniform conditions by methods self-evident or already indicated, we find

	A	R	D	θ	E. I.	M. F.	A′	t	t'
June 4 and 5.	25	4·84	9·06	36°	7·60	16·18	25	25	28
June 8.	25	4·89	9·22	36°	7·60	16·20	25	25	28
Mean.	25	4·87	9·14	36°	7·60	16·5	25	25	28

No. 7.

	A	R	D	θ	E. I.	M. F.	A′	t	t'
June 4.	25·2	6·84	1·955	36° 47′	7·68	16·52	23·35	24°	24°
June 5.	25·1	6·56	1·975	37° 57′	7·68	16·65	24·03	29°	31°
Mean.	25·15	6·70	1·970	37° 22′	7·68	16·59	23·69	26½	27½
June 7.	23·92	6·35	2·05	37° 25′	7·74	16·54	23·50	29	26
June 7.	24·4	6·36	1·70	37° 13′	7·82	16·64	23·60	30	31
Mean.	24·16	6·36	1·875	37° 19′	7·78	16·59	23·55	29½	28½

* The { embraces complementary sets.

June 11.	24·97	7·00	1·985	36° 23′	7·84	16·39	23·80	27	25
June 11.	24·95	6·82	1·625	36° 45′	7·86	16·57	24·27	28½	28½
Mean.	24·96	6·91	1·805	36° 34′	7·85	16·48	24·03	28	27

Reducing the three means to uniform conditions we find

	A	R	D	θ	E. I.	M. F.	A′	t	t'
June 4 and 5.	25	6·62	1·886	36°	7·60	16·6	25	25	28
June 7.	25	6·26	1·825	36°	7·60	16·5	25	25	28
June 11.	25	6·69	1·778	36°	7·60	16·1	25	25	28
Mean.	25	6·52	1·86	36°	7·60	16·4	25	25	28

The observations made with weaker magnetic fields will be given with somewhat less detail:

No. 5.

	A	R	D	θ	E. I.	M. F.	A′	t	t'
June 14.	8.21	2·81	5·00	35° 13′	7·75	9·44	8·22	28	27
Reduced.	8·33	2·80	5·20	36° 0′	7·60	9·38	8·33	25	28

No. 7.

June 14.	8·37	4·72	1·377	36° 23′	7·83	9·51	8·3	28	23
June 14.	8·20	4·63	1·442	36° 1′	7·80	9·41	8·12	28	31
Reduced mean.	8·33	4·57	1·409	36°	7·60	9·34	8·33	25	28

No. 5.

June 18.	7·34	2·63	4·86	34° 28′	7·84	8·76	7·15	31	32
Reduced.	7·25	2·53	4·98	36°	7·60	8·56	7·25	25	28

No. 7.

June 18.	7·72	4·51	1·337	35° 9′	7·85	9·02	7·55	31°	29°
June 18.	6·74	4·11	1·332	35° 13′	7·85	8·35	6·52	31°	35°
Reduced mean.	7·25	4·18	1·349	36° 0′	7·60	8·57	7·25	25°	28°

In the above tables no corrections have been applied with reference to the facts, already discussed, that the test-coil is not used in just the same manner as the loops on the crosses, or to the further fact that the readings of the ballistic galvanometer scale are proportional to the tangent of twice the deflection instead of being proportional to the sine of one-half the deflection. In the table which follows, and which is in the main derived from those going before, corrections are applied with these points in view.

No. 5.

Int. of mag. field.	D × (thickness of cross) / Int. of mag. field.	R (corrected) / 2 × area of loop.		M. F. (corrected) / Area of test-coil.		Mag. ind. in cross / Mag. ind. of field.	D × (thickness of cross) / R (corrected).
16,350	280×10^{-9}	3·15	÷	3·12	=	1·01	·929
9,360	278×10^{-9}	1·83	÷	1·79	=	1·02	·910 } .928
8,540	292×10^{-9}	1·69	÷	1·63	=	1·04	·947 } .928
4,900	(July 3,'88: no observations on tr'nsv'rse current.)					1·02	----

No. 7.

16,250	343×10^{-9}	4·22	÷	3·10	=	1·36	·848	
9,320	454×10^{-9}	2·99	÷	1·78	=	1·68	·907	} 919
8,550	473×10^{-9}	2·79	÷	1·63	=	1·71	.931	
4,900 (July 3.)		----		----		1·75	----	

The last column shows that with fields of medium strength the relatively greater transverse effect in the thick cross corresponds closely to the more intense magnetic induction through this cross.

The difference between the second and third values for No. 5 in this column, and also that between the second and third values for No. 7, must be regarded as mainly accidental, a fact which shows the need of caution in drawing numerical conclusions from this series of results. It appears, however, that the transverse effect in the thin cross, No. 5, maintains a nearly constant ratio to the magnetic induction through the same when the magnetizing field is increased from about 9000 to more than 16,000; but that with a similar increase of magnetizing field the transverse effect in the thick cross, which attains an extremely high degree of magnetization, does not increase enough to maintain unchanged its ratio to the magnetic induction through the cross.

(To be continued.)

Art. XV.—*Analyses of the Waters of some American Alkali Lakes*; by Thomas M. Chatard.

In the course of the geological examination, by the U. S. Geological Survey, of the Great Basin or country lying between the Rocky Mountains and the Sierra Nevada, samples of the waters of most of the lakes of that section were collected and sent for analysis to the laboratory of the Survey. Many of these analyses were published in Bulletin No. 9, U. S. Geol. Survey, but when I began a special study of the more important sources of natural alkalies, for the purpose of preparing the way for their practical utilization, a re-examination was, in some cases, deemed advisable and samples were also obtained from Owen's Lake, California, a locality not visited by the Great Basin party.

The four analyses here given represent the most important alkali lakes so far known and as the waters of two of them are now being utilized, it is believed that the information will prove of interest.

The analytical methods used are, in general, well known. The carbonic anhydride was, in all cases, determined by dis-

tillation, being collected and weighed in a potash bulb. For the boric acid, in the water of Owen's Lake, the excellent method of Gooch* was followed; for the Mono and Ragtown waters the process of Stromeyer, with modifications of my own, was used, but, though giving very fair results, the process cannot be compared for ease, simplicity and accuracy with the former method.

The determination of the alkalies in such very dense waters was, at first, found to be difficult, owing to the large quantities necessarily taken. To get determinations which shall be fairly accurate when referred to a liter, portions of not less than 50 c.c. should be taken, the water in all cases being carefully weighed. The amount of alkaline chlorides corresponding to 50 c.c. of such waters is very large, and, when the final evaporations are being made, there is great liability to loss, owing to the formation of a salt crust on the surface of the liquid and subsequent spirting caused by steam and ammonia vapor produced under the crust. This takes place no matter how carefully the evaporation be carried on, and many determinations were thus lost.

The use of hydrochloric acid enables us, however, to completely obviate this difficulty. The purified alkaline chlorides are to be evaporated till crystallization begins; the platinum vessel is then removed from the water bath and an equal bulk of very pure, highly concentrated hydrochloric acid added to the solution. A copious precipitation of finely granular salts at once ensues, and, on replacing the vessel on the water bath, evaporation goes on quietly and rapidly, no salt crust is formed, and when the final heating is given, little decrepitation occurs. In this manner, it is as easy to handle several grams of chlorides and to obtain accurate determinations as it is when we have to deal with the far smaller quantities usual in mineral analysis.

Of the four lakes to be considered, the most northern one is Abert Lake, in south-eastern Oregon. The sample analysed was "collected by H. T. Biddle at middle of west side of lake, one foot below surface, 30–40 feet from shore, September, 1887." The total quantity at my disposal was about 200 c.c., an amount too small for any extended research, but sufficient for all practical purposes. For each determination, 25 c.c. = 25·7792 grams were taken.

Specific Gravity, 1·03117 at 19.8°.

* Gooch, Proc. Am. Acad. Sci., 1886, p. 167.

	Contents in 25 c.c. A.	B.	Average.	In 1 Liter.	Per cent.
SiO_2	·0063	·0053	·00580	·232	·59
K	·0133	·0136	·01345	·538	1·37
Na	·3674	·3671	·36725	14·690	37.51
SO_3	·0148	·0146	·01470	·588	1·50
O	·0030	·0029	·00295	·118	·30
CO_2	·1755	·1757	·17560	7·024	17·93
O	·0615	·0616	·06155	2·462	6·28
Cl	·3365	·3366	·33655	13·462	34·67
H				·058	·15
				39·172	100·00

Hypothetical Composition.		Per cent.
SiO_2	·232	·59
KCl	1·027	2·62
NaCl	21·380	54·58
Na_2SO_4	1·050	2·68
Na_2CO_3	10·611	27·09
$NaHCO_3$	4·872	12·44
	39·172	100·00

Proceeding southwardly, we have next the "Big Soda Lake" near Ragtown, Churchill Co., Nevada. This, with the adjoining "Little Soda Lake," has been very fully described by King* and by Russell,† and my own observations, during my short stay at this place, were confined to the technical aspects of the manufacture of carbonate of soda, which is carried on at both lakes.

The sample of the water of the "Big Lake," of which the analysis is here given, was collected by Mr. Russell in 1881, and was taken at the depth of one foot. The analysis was made in 1884 and was published in Bulletin No. 9, U. S. Geol. Survey, the CO_2 being then determined by difference. Since then it has been carefully determined in duplicate, with the following results.

Specific Gravity, 1·0995 at 19·8°.

	In 1 Liter.	Per cent.
SiO_2	·304	·24
Mg	·270	·21
K	2·520	1·95
Na	45·840	35·53
B_4O_7	·314	·24
SO_4	12·960	10·05
CO_3	20·934	16·23
Cl	45·690	35·41
H	·181	·14
	129·013	100·00

Hypothet. Composition.		Per cent.
SiO_2	·304	·24
$MgCO_3$	·862	·67
KCl	4·817	3·73
NaCl	71·507	55·42
Na_2SO_4	19·170	14·86
$Na_4B_4O_7$	·402	·31
Na_2CO_3	16·731	12·97
$NaHCO_3$	15·220	11·80
	129·13	100·00

Mono Lake, Mono Co., California, is next in succession. This locality is described at length by Mr. I. C. Russell in his paper, "The Quaternary History of Mono Valley, California," which will shortly appear in the 8th Annual Report of the U. S. Geological Survey; for the present it suffices to say that this large body of water, of a composition so favorable to utilization, is, for practical purposes, inaccessible, and that the high altitude and consequent shortness of the evaporating sea-

* King, Clarence, U. S. Geol. Expl. 40th Parallel, vol. i, pp. 510–513.

† Russell, I. C., Geological History of Lake Lahontan, U. S. Geological Survey. Monographs XI.

son would, under any circumstances, render the success of any industry established there very doubtful.

The sample analyzed was collected by Mr. Russell in 1882 and was taken at the depth of one foot, on east side of lake.

Specific gravity, 1·045 at 15·5°.

	In 1 Liter.	Per cent.	Hypothet. Composition.		Per cent.
SiO_2	·0700	·12	SiO_2	·0700	·13
K	·9614	1·79	$(Al_2Fe_2)O_3$	·0030	·005
Na	19·6853	36·81	$CaCO_3$	·0500	·09
Ca	·0200	·037	$MgCO_3$	·1928	·36
Mg	·0551	.10	$Na_4B_4O_7$	·2071	·39
$(Al_2Fe_2)O_3$	·0030	·005	KCl	1·8365	3·44
SO_4	6·6720	12·480	NaCl	18·5033	34·60
CO_3	13·6963	25·61	Na_2SO_4	9·8690	18·45
B_4O_7	·1600	·30	Na_2CO_3	18·3556	34·33
Cl	12·1036	22·64	$NaHCO_3$	4·3856	8·20
H	·0522	·10			
				53·4729	100·00
	53·4729	100·00			

Finally, at the southern end of the series, we have Owen's Lake, Inyo Co., California. This lake has been described by Oscar Loew in Wheeler's Report for 1876, pages 189–194, and upon it most of my field work for 1886 and 1887 has been done. Its greatest dimensions, as given by Loew, are seventeen miles long by nine miles wide, its greatest depth fifty-one feet, and it contains, according to his calculation, 22,000,000 tons of carbonate of soda. The Inyo Development Co. has begun the manufacture of soda at this point and to it I am indebted for every needed facility for making observations on the evaporation of the water and on the various salts obtained by its fractional crystallization. These products, together with others since obtained, are under examination and the results will be published later.

The sample analyzed was taken by myself, Sept. 17, 1886. Portions of 100 c.c. were taken for each determination, the duplicates agreeing very closely.

Specific gravity, 1·062 at 25°.

	In 1 Liter.	Per cent.	Hypothet. Composition.		Per cent.
SiO_2	·220	·28	SiO_2	·220	·28
K	1·644	2·13	$(Al_2Fe_2)O_3$	·038	·13
Na	28·500	36·96	$(CaMg)CO_3$	·055	
Ca	·014	·02	$Na_4B_4O_7$	·475	·63
Mg	·005	----	KCl	3·137	4·07
Fe_2O_3	·014	·02	NaCl	29·415	38·16
Al_2O_3	·024	·03	Na_2SO_4	11·080	14·38
SO_4	7·505	9·73	Na_2CO_3	26·963	34·95
B_4O_7	·367	·49	$NaHCO_3$	5·715	7·40
CO_3	19·398	25·16			
Cl	19·344	25·09		77·098	100·00
H	·063	·10			
	77·098	100·00			

In comparing such analyses, to determine the practical value of a given water for soda making, the relation of the amount of sulphate to the total amount of carbonate is of the greatest importance, since the greater the relative amount of sulphate, the more difficult it will be to obtain a high grade carbonate by simple solar evaporation. If this relative amount is small, a large excess of chlorides may be present without materially complicating the process. The relation between the monocarbonate and the bicarbonate should, for best results, be a molecule of each plus an excess of monocarbonate. The amount of necessary excess is not yet accurately determined but is probably under a molecule. Judged by this standard, the water of Abert Lake is the best, Ragtown the worst, of those here considered, while Owen's Lake, occupying a middle position as regards purity, is, owing to its geographical position and climatic environment, probably the one best adapted for practical utilization.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Molecular weight of Nitrogen peroxide.*—Vapor density methods appear incapable of establishing definitely the molecular constitution of nitrogen peroxide, although rendering it probable that at low temperatures this substance is represented by the formula N_2O_4. Ramsay has therefore applied to this question a method founded upon the researches of Raoult, which have proved that the depression of the freezing point of a liquid caused by the presence of dissolved liquid or solid is proportional to the absolute amount of substance dissolved and inversely proportional to its molecular weight. Raoult found the law to hold almost universally, the exceptions being very few. Thus using glacial acetic acid as the solvent, he found that out of 150 substances examined, scarcely half a dozen gave abnormal results. Ramsay's apparatus consisted of a wide test tube closed with a rubber cork, having two holes, through one of which a thermometer passes and through the other a glass tube in which plays a stirrer. The apparatus is placed in a beaker, and by adding hot or cold water, its temperature may be raised above or depressed below the freezing point of the solvent. In a first experiment 41·02 grams of glacial acetic acid were weighed into the apparatus, its melting point being 16·680°. A small bulb of nitrogen peroxide, containing 0·378 gram, was then broken in the acetic acid by means of the stirrer, and the melting point again observed. It was found to be 16·300°, having been lowered 0·380°. Hence one per cent of the peroxide would have lowered the melting point

0·4214°. Since 0·4214°×94·6=39, the constant obtained by Raoult for acetic acid, it follows that the molecular weight of the peroxide from this experiment is 94·6. A second quantity of 0·5085 gram peroxide was then crushed in the apparatus and lowered the melting point to 15·825°; corresponding to the molecular weight 98·58. Other determinations gave 92·11, 92·07, 93·18, 90·29. In a second experiment 40·05 grams of acetic acid, melting at 16·675°, had its melting point lowered to 15·768° by 0·893 gram of the peroxide; corresponding to a molecular weight of 95·87. Hence the author concludes that the molecular weight of nitrogen peroxide in the liquid state at about 16° is 92 and that its formula is N_2O_4. Moreover since, in the above experiments, the relative number of molecules of the peroxide in a given volume of acetic acid was decreased from 8·97 to 0·92 without changing its molecular weight it would appear that no dissociation of the peroxide takes place on dilution. Experiments with nitrogen trioxide, made by passing NO through N_2O_4 dissolved in acetic acid gave no reliable results since at 16° the trioxide was dissociated.—*J. Chem. Soc.*, liii, 621, June, 1888. G. F. B.

2. *Index of refraction of metals.*—A. KUNDT gives a brief account of his method of making metallic prisms of extremely small angle, which allow light to pass through. Most of the metallic prisms were deposited by electrolysis upon platinized glass. To accomplish this it was necessary to obtain a homogeneous and plane surface of platinized glass. After many trials Kundt succeeded in fusing with the glass, at a low red heat, the platinum layer. Vertically over a strip of this platinized glass, which was placed horizontally, is an electrode of the metal which is to be deposited upon the platinum. This electrode makes a small angle with the horizontal surface and includes a capillary layer of a suitable electrolyte. Frequently fifty or more trials have to be made before a suitable transparent wedge of the metal is formed which can be used to refract light. The prisms were also formed by exposing a glass plate to platinum wire raised to a white heat by an electrical current. The glass becomes covered with a layer of finely divided platinum. In order to form the wedge-shaped surface a piece of platinum foil 0·015^{mm} thick, 6^{mm} broad and about 45^{mm} long was placed with the broad sides vertical closely over a horizontal glass plate. In this way a double wedge is formed on the glass, consisting of a mixture of platinum oxide and platinum. By slight warming, the mixture can be converted into pure platinum. These metallic wedges were also formed in a vacuum by the above process, with very small angle of prism. The simple expression for index of refraction is $N=\frac{\alpha+\delta}{\delta}$, in which N is index of refraction, δ is angle of prism and α the deviation of the ray. These small quantities were measured by the micrometer of a Meyerstein spectrometer. Various control methods were employed to secure accuracy of measurement. The velocity of light in silver is nearly four times greater than

in a vacuum. The dispersion in silver is however not great. The velocity in gold and copper is also greater than in a vacuum, and the dispersion normal. In other metals the dispersion was found to be abnormal. The theoretical conclusions of Beer and Voigt in so far agree with the results of Kundt to a remarkable degree. If we call the velocity of light in silver 100, we have the following:

Silver.	Gold.	Copper.	Platinum.	Iron.	Nickel.	Bismuth.
100	71	60	15·3	14·9	12·4	10·3

With the exception of bismuth, this series is the same as that of the electrical resistance of metals. The number for copper however is somewhat small and may be due to impurity. The ratio of the heat conduction and electrical resistance of bismuth is still in question. From the above numbers one is tempted to conclude that the electrical resistance is proportional to the velocity of light of great wave length. We have here a relation between electricity—conduction of heat and velocity of light—Kundt is tempted to believe that the slowness of heat conduction in metals is due to the radiation from one layer to the adjoining, whereas the radiation itself in metals has the velocity of light. What we call electricity moves in a conductor with the velocity of light.—*Ann. der Physik und Chemie*, pp. 469–489, No. 7, 1888.

J. T.

3. *Resistance of square bars to Torsion.*—T. I. DEWAR calls attention to an error which has crept into various articles, including Prof. Ewing's on the Steam Engine in the Encyclopædia Brittanica, Sir William Thomson's article on elasticity in the same encyclopædia, Thomson and Tait's Natural Philosophy, and Minchen's Statics. The moment of resistance of a square bar to torsion is given by Saint Venant as $0{\cdot}281\,fh^3$ where f=maximun intensity of stress and h=side of square. Saint Venant gives the correct formula afterward as $0{\cdot}208\ fh^3$. "It seems strange that the talented author of the expressive distinctions, strain and stress, should himself have taken the formula for the strain instead of that for the stress." At the time he wrote however strain and stress were supposed to be proportional to each other.—*Nature*, p. 126, June 7, 1888. J. T.

4. *Latent heat of evaporation of Water.*—Regnault's experiments were made at temperatures above 0° and he obtained a formula which led to the value 607 units of heat, the latent heat of evaporation at 0°. Dr. DIETERICI, by the use of an ice calorimeter has made a direct determination of this constant, and has obtained the value 596·4 thermal units at 0°.—*Nature*, p. 143, June 7, 1888.

J. T.

5. *Electrolysis by alternating currents of Electricity.*—M.M. MANEUVRIER and J. CHAPPUIS show that the size of the electrodes exercises a great influence in the electrolysis by alternating currents. With currents of 250 to 300 volts and 4 to 5 Ampères, no trace of electrolysis can be discovered with electrodes of $0{\cdot}1^{cm}$ in diameter and 4^{cm} to 5^{cm} in length. If one however sub-

stitutes in the same voltameter some very fine electrodes there is an abundant disengagement of gases. The authors give various examples to show that electrolysis by alternating currents is different from that by continuous currents. By a suitable choice of electrolyte, an alternating current can be measured by a voltameter.—*Comptes Rendus*, p. 1719, June 18, 1888. J. T.

6. *Electro-chemical Radiophone.*—CHAPERON and MERCADIER employ a galvanic cell composed of one plate of silver coated by electrolysis of sulphide of sodium with a very thin layer of sulphide of silver, and another plate of silver. Both plates are placed in a liquid conductor, water acidulated with sulphuric acid, for instance. The cell possesses a very feeble electromotive force. It polarizes very rapidly and gives rise to variable instantaneous currents under the action of very feeble light. By means of a radiophonic wheel an intermittent beam of light corresponding to a tone of 1000 vibrations was allowed to fall on the cell, and the note was heard in a telephone enclosed in the circuit. This note was due to an electrochemical effect, the duration of which was less than $\frac{1}{2000}$ of a second.—*Comptes Rendus*, No. 23, p. 1595. June 4, 1888. J. T.

II. GEOLOGY AND MINERALOGY.

1. *On the Black Hills of Dakota;* by Prof. W. O. CROSBY.—A paper in the Proceedings of the Boston Society of Natural History for March 7, 1888 (p. 488), describes the rocks of the Black Hills, and shows that the great granite masses, which occur in the western portion of the Archæan area, consist really of vein granite. This is shown by their position and coarseness of texture. He makes also the important observation that the high conical masses of rhyolyte and trachyte of the northern end of the Black Hills, described by Prof. Henry Newton, are true laccoliths. Speaking of the Paleozoic rocks he remarks on the perfect conformability of the Carboniferous beds on the Cambrian with which they are in contact, the intervening Silurian and Devonian being absent. The unconformability of the Cambrian on the Archæan is to be seen at all contacts.

2. *Annual Report of the Geological Survey of Pennsylvania for* 1886.—Parts II and III of this report have been issued. Part II treats of the Oil and Gas Region, and contains the detailed report of Mr. J. F. Carll, covering over 200 pages and also a paper on the Chemical Composition of Natural Gas by Prof. F. C. Phillips. The gas of Fredonia, N. Y., was found to contain 90·05 p. c. of hydrocarbons of the paraffin series (in which methane predominates), 9·54 nitrogen and 0·41 carbon dioxide. This is about the average of the results obtained. But the Murrysville gas, a very productive well, afforded 97·70 of paraffins and only 2·02 nitrogen, and 0·28 CO_2; while the Houston gas, from a well two miles south of Canonsburg, Pa., afforded 84·26 paraffins, 15·30 of nitrogen and 0·44 CO_2.

Part III consists of the Report of Mr. Frank A. Hill on the Anthracite Coal Regions.

3. *Geological and Scientific Bulletin.* Published by the Texas State Geological and Scientific Association, at Houston, Texas. (Fifty cents per annum).—No. 2 of this new Geological publication bearing the date of June 2, 1888, is a four-paged folio. It contains geological communications on Texas and Arkansas by Mr. R. T. Hill and others, besides papers bearing on the mining industry of Texas. The region is to be surveyed under State auspices, and the paper will announce results as they may be developed and also report on observations in other departments of science. The survey has been put under the direction of the Commissioner of Insurance, Statistics and History, and by him the geologists will be appointed. An appropriation of $15,000 has been already made.

4. *The Genealogical Tree.*—Prof. J. W. Judd, in his excellent Anniversary Address of February last before the Geological Society of London, has the following wise remark: "One of the most mischievous weeds that have accompanied the evolutionist in his incursions into various parts of the biological field is the preposterous 'genealogical tree.' We can scarcely turn over the leaves of a modern systematic work without finding it flourishing in full luxuriance. No sooner has the student of a particular group arranged his families, genera, and species, than he thinks it incumbent upon him to show their genetic relations. Very admirably has Professor Alexander Agassiz pointed out the utter fatuity of such a proceeding. As Lyell used to say, in speaking of such proceedings, the imagination of the systematist, untramelled by an acquaintance with the past history of the group, 'revels with all the freedom characteristic of motion *in vacuo*.' If for no other reason, zoologists and botanists ought to study fossil forms in order that, by encountering a few hard facts in the shape of fossils, they may be saved from these unprofitable flights of the imagination."

5. *Estudo sobre os Bilobites e outros Fosseis das Quartzites da Base do systema Silurico de Portugal.* Supplement: by J. F. N. Delgado, Director of the Geological Survey of Portugal. 76 pp. 4to, with 9 plates.—This supplementary report by Prof. Delgado consists largely of a reply to the criticisms of M. Nathorst in his report on the same subject of 1887, but contains also descriptions and figures of new kinds. The plates are phototypes, and represent some remarkably fine and large forms; they appear to sustain the author's conclusions as to their vegetable origin. The last two plates represent large species having the markings of *Arthrophycus Harlani* of Hall, making this genus (if not the species) of much earlier date than known from the American rocks. Prof. Delgado names them *A. Harlani*, although much larger than the American species.

6. *British Petrography with special reference to the Igneous Rocks;* by J. J. Harris Teall, M.A., F.G.S. 451 pp. 4to, with

47 plates. London, 1888 (Dulau & Co., Soho Square).—The numerous active workers in English petrography, among whom the author of the present work is included, have shown that a remarkably wide range of igneous rocks is included in the confines of Great Britain. To give a complete and systematic account of these, within the compass of a single volume, is a serious task, but one which the author has accomplished in an admirable manner. A minute personal knowledge of the rocks themselves, and wide reading of the literature of the subject abroad, has equipped him well for the work. The opening chapters are devoted to a general statement as to the forms taken by the constituents of igneous rocks, and to a discussion of the chemical and physical characters of the rocks. The author wisely regards rocks, not so much from a narrow mineralogical point of view, with reference only to the minerals of which they are composed, but more broadly with regard to their general chemical composition. He also shows independence in cutting loose from the age criterion as a fundamental basis for classification and nomenclature. He insists strongly upon the distinction between the basic and acidic members of the rock series. In this connection he emphasizes the effect of crystallization on an igneous magma to increase the relative amount of silica and alkalies, and further in the alkalies to increase the potash relatively to the soda. He quotes here a series of analyses, from widely different sources, bringing out these facts and refers to the work of Rosenbusch as showing that they are confirmed by microscopic examination.

The classification adopted divides the rocks into a series of groups passing from the basic to the acidic, according to the chief mineral constituents present; further, under each group the distinction in structure between "*granitic*" and "*trachytic* texture" forms a basis of further subdivision.

The first group includes the so-called ultra-basic rocks, that is, those made up of olivine alone, or with some form of pyroxene or amphibole without feldspar. The basic group follows, the rocks characterized by plagioclase with olivine, pyroxene, amphibole and biotite. This passes through the rocks of intermediate composition to the third group characterized by the presence of orthoclase with the various other minerals named. The rocks containing nephelite and leucite follow and then certain forms not easily included in the preceding divisions. The glassy and fragmental rocks close the series. Under each group a general summary is given of the constituent minerals and of the rocks as they appear elsewhere; in this portion of the work the author shows a full knowledge of the extended literature of the subject. Then follows a somewhat minute account of the British rocks falling into the place, based upon the exhaustive studies of Judd, Allport, Rutley, Worth, Teall and others. Of the various rock types falling into the groups mentioned, the majority are fully represented and have been thoroughly studied; certain kinds, however, for example those of the nephelite, leucite series, the

recent andesites, are absent; only a single case of a rock with nephelite being known. A series of forty-seven plates accompanies the text description. These are of excellent execution, well drawn and very delicately colored, and with key plate accompanying each, show clearly the many points to be illustrated.

7. *Brief notices of some recently described minerals.*—LANSFORDITE.—A white translucent mineral, somewhat resembling paraffin, but having a crystalline structure and vitreous luster; a prismatic angle of 76° was measured. Hardness 2·5, specific gravity 1·54–1·692. An analysis by Keeley gave

$$CO_2\ 18{\cdot}90,\ MgO\ 23{\cdot}18,\ H_2O\ 57{\cdot}79 = 99{\cdot}87.$$

Of the water, the loss over H_2SO_4, after 20 hours, was 4·83 p. c., after 48 hours 11·70, after a week 26·33, at 110° C. 12·31, at 185° C. 9·76, at a red heat 9·39. The formula deduced is $3MgCO_3, Mg(OH)_2 + 21H_2O$. The mineral was found as a stalactitic growth at the anthracite mine of Lansford, near Tamaqua, Schuylkill Co., Penn.—F. A. GENTH in *Zeitschr. Kryst.*, xiii, 255.

HORSFORDITE.—A massive mineral resembling native silver in color, with high luster, but soon tarnishing. Hardness 4–5, G.=8·812. An analysis gave

$$(\tfrac{2}{3})\ \text{Antimony}\ 26{\cdot}86.\ \text{Copper}\ 73{\cdot}37 = 100{\cdot}23$$

which corresponds to a compound between Cu_5Sb and Cu_6Sb, very near to $Cu_{11}Sb_2$. It is thus related to some forms of dyscrasite, also to algodonite. It occurs as an extensive deposit near Mytilene in Asia Minor.—A. LAIST and T. H. NORTON in *Amer. Chem. Journ.*, x, 60.

HOHMANNITE, AMARANTITE.—Described as two independent hydrous iron sulphates, occurring with copiapite from Chili. Hohmannite is a chesnut-brown massive mineral with a fibrous structure. Hardness 3, specific gravity 2·24. An analysis gave

$$SO_3\ 30{\cdot}88,\ Fe_2O_3\ 40{\cdot}05,\ H_2O\ 29{\cdot}63 = 100{\cdot}56$$

for which the formula $2Fe_2O_3, 3SO_3 + 13H_2O$ is calculated. Amarantite occurs in microscopic crystals of an orange color. The analysis gave

$$SO_3\ 37{\cdot}26,\ Fe_2O_3\ 35{\cdot}58,\ H_2O\ 27{\cdot}62 = 100{\cdot}46$$

leading to the formula $Fe_2O_3, 2SO_3 + 7H_2O$. A later trial of hohmannite gave a result nearly identical with this, making it probable that the two minerals have really the same composition and are identical, though occurring in a different form. A. FRENZEL in *Min. Petr. Mitth.*, ix, 397, 423.

QUENSTEDTITE, BÜCKINGITE.—In a preliminary notice of some iron sulphates from Chili, the name *Quenstedtite* is given to a salt occurring in reddish-violet tabular crystals resembling gypsum. They belong to the monoclinic system and have the composition

$$2FeO_2H + 8Fe_2(SO_4)_3 + 10aq.$$

Bückingite occurs in dark brown thick tabular crystals belonging to the triclinic system. The formula given is

$$2Fe_2(SO_4)_3 + 2H_2SO_4 + 7FeSO_4 + 60aq.$$

—G. LINCK in *Jahrb. Min.*, vol. i, 213, 1888.

8. *Mineralogical Notes.* (1) *Vesuvianite from Newbury, Mass.;* by W. O. Crosby and James T. Greeley.—An investigation with analysis of a massive mineral occurring with serpentine in the lime quarries of Newbury, Mass., has proved that it is vesuvianite, and not massive garnet, as has been supposed (Dana's Mineralogy).

(2) *Gahnite from Rowe, Mass.;* by W. O. Crosby and Charles L. Brown.—A partial analysis is given of the zinc spinel occurring with pyrite at Rowe, Mass. The authors announce the occurrence as a new discovery, evidently not having seen the paper on the subject by A. G. Dana, published three years since (this Journal, xxix, 455).—*Technology Quarterly,* i, 407, 408, May, 1888.

9. *Brazilian Meteorites.*—Seven Brazilian meteorites are represented in the collection of the National Museum of Rio de Janeiro of which only three (Bendego, Santa Catherina and Macau) have been previously described. The new ones are: *Itapicuru-mirim* (Prov. de Maranhão) March, 1879, chondrite, weight 2·024 grams, spec. grav. 3·638. *Santa Barbara* (Prov. de Rio Grande do Sul) Sept. 26, 1873, chondrite, weight of two authentic specimens, representing apparently about a quarter part of the single stone collected, 93·211 grams, spec. grav. 3·478. *Minas Geraes?* Date and place of fall unknown, but supposed to be from the province of Minas Geraes, chondrite, weight 1·224 grams, spec. grav. 3·48–3·51. *Angra dos Reis* (Prov. de Rio de Janeiro) Jan. 15–31, 1869, Angrite (Ludwig and Tschermak, Min. Mitth., 1887), weight of a piece representing about a quarter part of the original mass, 446·5 grams, spec. grav. 3·43–3·47; composition augite 93·28, olivine 5·45, magnetic pyrites 1·27.

A fragment of a chondrite labeled "Rio de Janeiro" is presumed to belong to the Santa Christina meteorite. A stone from Ponta Grossa, province of Paraná, sent to the Emperor in 1867 and described as having a syenitic aspect with a wrinkled reddish crust (Eukrite or Howardite?) has disappeared. A fragment of iron in Claussen's collection presumed to be the one referred to by him (Bull. de l'Acad. Bruxelles, 1841) under the name of the Curvelle meteorite, is artificial, as is also a reputed meteorite at Areado, in the province of Minas Geraes. Another pseudo-meteorite is an artificial mass of metal said to have fallen June 14, 1861, near Curitiba, prov. of Paraná. It has not yet been definitely ascertained if a meteorite fell on that day or not. Meteorites are also reported from Morro do Chapeo and Monte Alto in the province of Bahia in regard to which no definite information has been obtained.—(*O. A. Derby,* in *Revista do Observatorio of Rio de Janeiro.*

10. *Note on the Locality of the Santa Catharina Meteorite.*—The masses of iron known by this name were found scattered over a triangular area of about 10,200 square meters at a distance of 4,200 meters from the city of São Francisco do Sul on the island of the same name. This portion of the island is composed of gneiss and granite cut by dykes of diabase. The soil about

the iron is clearly of granitic origin and large blocks of tourmaliniferous granite occur close by one of the points where iron was found. No evidence of the existence of basic eruptive rocks such as are required by the hypothesis that the iron is similar in origin to that of Ovifak could be found in the vicinity, though from the lack of rock exposures, the depth of the soil cap and the thick covering of second growth timber, it cannot be positively affirmed that none such exist. On the whole the evidence, though not conclusive, is in favor of the meteoric rather than the terrestrial origin of the iron. About 25000 kilograms are reported to have been shipped to England to be smelted for nickel. The only fragments to be found at present are almost entirely reduced to the state of oxide.—(*Luiz F. Gonzaga de Compos* in *Revisto de Observatorio of Rio de Janeiro*).

11. *The Bendego Meteorite.*—This famous mass of iron was landed in Rio de Janeiro June 15th, and is now in the National Museum of that city. The transportation over 115 kilometers of mountainous country to the nearest railroad station was directed by Chevelier José Carlos de Carvalho in the name of the *Sociedade de Geographia de Rio de Janeiro*, the necessary funds, amounting to about $10,000, being generously furnished by Baron Guahy. The weight verified on the scales of the Bahia R. R. is 5,361 kilograms. The comparative thickness of the crust of oxide formed since the first attempt to remove it in 1785, and that found in the original resting place, afford a basis for a rough guess at its age which may safely be put down as over six centuries.

III. Botany.

Notices of recent contributions to Vegetable Physiology.—(For other recent papers, bearing more particularly on the vegetable cell, see this Journal, March, 1888).

(1) *A. H. de Vries's studies of Glycerin in its relations to certain tissues.*—In Botan. Zeitung for April 1888, this investigator publishes a few notes in regard to the absorption of glycerin by vegetable cells, which have a high degree of interest for all who are in the way of examining the behavior of cells when placed in this medium. It was shown by Klebs last year that this substance is very easily taken up by the cells of living Zygnema, diffusing with facility into their interior. Moreover it was pointed out by Arthur Meyer in 1886, that when the green parts of plants are placed in glycerin it is possible for them to produce starch therefrom, a fact of great importance in view of the fact that glucose has been synthetically produced from glycerin-aldehyd (Fischer and Tafel, 1887). But, as is well known, glycerin is a powerful plasmolytic, acting in a 10 per cent solution to cause distinct contraction, and even in a much more dilute solution acting more or less plainly. After an hour or so, the contraction diminishes gradually and finally passes away, while in a solution of 5 per cent, growth takes place, and the Zygnema remains fresh and healthy even for four months in the dark.

It appeared therefore of importance to ascertain accurately the quantitative relations of glycerin to tissues, and this has been attempted by deVries in the paper referred to. His method is essentially the same as that employed by him in his previous series of plasmolytic experiments, and the material is the same, namely,—the red epidermis of the petiole of *Begonia manicata.* From the epidermis of the upper side of the petiole about twelve good microscopic slices are taken, and subjected at once to the action of the plasmolytics, such as potassium nitrate or sugar, of different degrees of strength. After two hours it is possible to detect in the sections placed in the stronger solutions the beginning of the plasmolysis, and afterwards one may trace its further progress in the weaker ones. From these observations deVries determines the isotonic coefficient for glycerin to be 1·78.

When this figure is compared with the coefficients of some other substances, and also with the figures obtained by Raoult for the lowering of the freezing-point, the curious relations are confirmed.

Glycerin,	1·78	17·1
Cane-sugar,	1·88	18·5
Inverted sugar,	1·88	19·3
Malic acid,	1·98	18·7
Citric acid,	2·02	19·3
Tartaric acid,	2·02	19·5

deVries has also measured the permeability of the protoplasts by glycerin, but he gives only a few results as an example of the working of his general method.

(2) *Assimilation by colored and variegated leaves.*—Engelmann to whom we are indebted for a method of quantitatively estimating the effects of different rays of the solar spectrum in assimilation, has extended his observations to variegated leaves, and to those which have a uniform color other than green. (Bot. Zeit., xlv. no. 25.) Passing over his studies as to the structure of the parenchyma of the leaves, and merely stating that he distinguishes between colors which depend (1) on the cell-wall, (2) on the cell-sap, and (3) on the plastids themselves, it may be said that he presents results confirming to a certain extent his former views as to the relation of the absorption-bands and assimilative activity. Without dwelling upon the possible errors of his method, it is enough to call attention to a marked advantage which it has over any other in the determination of the amount of activity in a single cell or group of cells. The method, it will be remembered, consists essentially in the application of a small direct-vision spectroscope under the stage, throwing the light through the diaphragm upon the under side of an object placed in the field. By the activity of bacteria in the water surrounding the object (assuming that this activity is due to the elimination of oxygen during the process of assimilation), Engelmann endeavors to ascertain the relative amount of assimilation in different parts of the spectrum. When, as in the case of large leaves or fragments of

green twigs employed in the ordinary method by exposing the whole to the different rays, it is seen that the greatest assimilation takes place in the orange rays, or those of medium refrangibility, it is impossible to detect any relation between the absorption bands and the amount of oxygen given off. Hence, with all the objections which may be urged against it, Engelmann's method places in our hands the means for estimating the effects in a strictly localized part of the field. When, therefore, the method is applied to the different parts of a variegated or colored leaf, we may reasonably expect to determine the difference in the efficiency of the rays belonging to the different parts of the spectrum. It is fair to say that the present paper appears to strengthen the position originally assumed by Engelmann in the questions to which his methods and conclusions have given rise. He has given also some useful hints as to the employment of his method which obviate a few of the objections formerly raised against it. G. L. G.

(3) *Hough's American Woods. Part I;* by ROMEYN B. HOUGH, Lowville, N. Y.—This work consists of transverse, radial, and tangential sections of twenty-five species of our North American woods, having a thickness of perhaps one-hundredth of an inch or in some cases a good deal less, and measuring two inches by a little more than four. A few of the specimens are somewhat thicker than this, but they are all sufficiently thin to reveal the structure of the wood. The sets are furnished at the low price of five dollars for the twenty-five species, and some of the species are represented by more than one series of sections. These sets remind one of the beautiful preparations made for schools by Mr. Spurr, under the direction of Mr. Henry Brooks of Boston, but they do not possess as those did, the advantage of protection by thin plates of mica, which rendered the latter of great service in botanical classes. Mr. Hough's specimens are equally beautiful, but in their unprotected condition one would hardly like to trust them in the hands of ordinary students. It is to be sincerely hoped that Mr. Hough will be encouraged to continue his interesting and useful work. The sections are accompanied by a short account of the elements of botany, together with the more important facts relative to woods, and the whole treatise is followed by a specific statement regarding all the plants used in the illustrations. G. L. G.

Journal of the Trenton Natural History Society.—The number of this Journal for January, 1888 (No. 3), contains a paper by Dr. A. C. Stokes on Fresh-water Infusoria, and one by W. A. Stowell on the Flora of Bergen Co., N. J.

Bulletin of the Natural History Society of New Brunswick, No. VII, published at St. John, New Brunswick, contains a review of the Echinodermata of New Brunswick, by Mr. W. F. Ganong.

OBITUARY.

AMOS H. WORTHEN, the distinguished geologist of Illinois, died on the sixth of May last, in his 75th year, leaving behind him, in the volumes of the Illinois Geological Survey, a lasting monument to his memory.* Mr. Worthen was born October 31, 1813, at Bradford, Orange County, Vermont, being next to the youngest of the thirteen children of Thomas Worthen and Susannah Adams. His mother was a descendant of the Adamses of colonial times. In August, 1834, he went with his young wife—having married in the January preceding Miss Sarah B. Kimball, of Warren, New Hampshire—to Harrison County, Kentucky, and there for a year or two taught school. In June, 1836, he moved to Warsaw, Illinois, which was his home until his death, with the chief exception of two years between 1842 and 1844 spent in Boston on account of Mormon troubles in Illinois. While engaged in commercial business, he became interested in the science of geology, and made large collections of fossils and also of the remarkable geodes of the Keokuk limestone in the region. On the institution of the Geological Survey of Illinois in 1851, under Prof. J. G. Norwood, he was selected as his assistant, and continued his labors in this position until 1855; but little was published as results of the survey owing to the inadequate appropriations by the State. From 1855 to 1857 he was assistant under Professors James Hall and J. D. Whitney in the Geological Survey of Iowa; and the large volume published in 1858 owes very much of its value and interest, says the Report, "to the labors of Mr. Worthen in the field, and for the loan of his magnificent collection of Carboniferous Crinoids, as well as of other fossils." "But for this liberality, the work would have been far less fully illustrated. Such collections can only be accumulated by the devoted attention of many years; and in expressing my own indebtedness to Mr. Worthen, I may express the obligations under which geology rests for this contribution, and which will be gladly acknowledged by every student and votary of science." The many beautiful plates of the large volume are from drawings by Mr. F. B. Meek, who was afterward associated with Mr. Worthen in the paleontology of his own reports. This Iowa Report with its many plates of wonderful Crinoids should bring to mind the name of Worthen.

In March of 1858, Mr. Worthen took charge, by State appointment, of the Geological Survey of Illinois. The survey was carried on until 1872. After this date, he continued the study and care of the collections, with the title of Curator of the Illinois State Museum, completing and issuing from time to time the large and copiously illustrated volumes of his Report. Already in 1860, advance results of his work, in connection with Mr. Meek, appeared in the Proceedings of the Academy of Natural Sciences

* For many of the particulars with regard to the life of Mr. Worthen we are indebted to Prof. T. B. Comstock.

of Philadelphia; one in September, describing 29 new species of Crinoids, and another in October, describing 69 new species of mollusks and other fossils; and these were followed by others of similar character.

The first and second volumes of his Geological Report made their appearance, in Royal Octavo, in 1866, the first, largely stratigraphical, the second, mainly paleontological. The latter contained descriptions and figures of 118 species of fossil fishes (by Newberry and Worthen), 156 of invertebrates, including Crinoids, etc. (by Meek and Worthen), and 50 of coal plants (by Mr. Lesquereux). These volumes were followed two years later by the third; and others slowly appeared, the seventh with 26 plates devoted to fossil fishes and others to Crinoids, etc., in 1883. Together the series is unsurpassed in importance by any of those of the other States, especially in the departments of Crinoids, Articulates, and Subcarboniferous Fishes.

Mr. Worthen left an eighth volume in the press. Besides these volumes of reports Mr. Worthen issued a large colored Geological Map of Illinois; published three volumes on the Economical Geology of the State compiled from his Geological Reports, and was the means of gathering for the State Museum one of the largest collections of fossils in the country.

In the early part of the survey Mr. Worthen encountered and overcame great opposition. His modesty and earnestness, high character and quiet dignity gave him great influence, and the many difficulties disappeared before him. Although nearly seventy-five years old at his death he had not given up work; the preparation of the text and plates illustrating the descriptions of the Silurian invertebrate fossils of Illinois, for the eighth volume, was occupying him, when a sudden attack of pneumonia brought all to an end. The Governor of the State, Governor Oglesby, in a telegram to the family, most fittingly said: "In his death the State loses a useful private citizen, a faithful public officer, and an ardent and laborious friend of Science."

Of the seven children of Professor Worthen, the only daughter died in infancy. His six sons are still living. The name of one, Charles K. Worthen, appears as the draftsman on many of the plates in the later volumes of his father's reports. Professor Worthen's wife died a year before him, on the 13th of January, 1887.

J. D. D.

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ERRATUM.

Page 73, line 18 from bottom, for *under charge of*, read *under a contract with*.

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THE

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[THIRD SERIES.]

ART. XVI.—*Cambrian Fossils from Mount Stephens, Northwest Territory of Canada;* by CHARLES D. WALCOTT.*

THE announcement of the discovery by Mr. Otto J. Klotz of a group of Cambrian fossils at Mt. Stephens, near the line of the Canadian Pacific railway, and a description of some of the species by Dr. C. Rominger, appeared in July, 1887.†

Dr. Rominger describes one new genus of the Trilobita, Embolimus, and five new species, and also mentions two other species of trilobites, several brachiopods, a species of Hyolithes and what he thinks may be a graptolite. There is no attempt made to give the stratigraphic position of the fauna in the Cambrian system, by comparison with published sections and descriptions, or to compare the species with similar forms that have been described from the Cambrian strata of the Rocky Mountains. He states that it was his intention to visit the locality, and, if he has done so, we may receive more information in relation to the occurrence of the fauna there.

Mr. Klotz presented to the U. S. Geological Survey a small collection of fossils from Mt. Stephens, and, through the kindness of Professor J. F. Whiteaves, Paleontologist of the Geological Survey of Canada, I have before me some very fine specimens, from the same locality, collected by Mr. McConnell.

* Read before the Biological Society of Washington, April 7th, 1888.

† Descriptions of Primordial Fossils from Mt. Stephens, N. W. Territory of Canada, Proc. Acad. Nat. Sci. Philad., pp. 12–19, Plate I, 1887.

When comparing this fauna with one collected from the Middle Cambrian Terrane in Central Nevada, I found that several of the species from the widely-separated localities were identical. This result led me to prepare the following notes, which I now present to your consideration.

The accompanying section is given to show the position of the Mt. Stephens fauna in the Cambrian system, as observed in the Highland range of Central Nevada, about 125 miles south of Eureka.*

			Feet.
1.	Dark reddish brown quartzite, evenly bedded and ripple-marked in some places		350
2.	Bluish-gray limestone		35
	Fossils: *Olenellus Gilberti.*		
3.	Buff argillaceous and arenaceous shales, more or less solid near the base and laminated in the upper portions		80
	Fossils: Annelid trails and fragments of Olenellus in the lower part. Higher up, the heads of *Olenellus Gilberti* and *O. Iddingsi* occur in abundance.		
4.	Light-colored gray limestone and bluish-black limestone		16
5.	Sandy, buff-colored shale		40
	Fossils: Annelid trails, *Cruziana* sp.?		
6.	Dark bluish black limestone		46
7.	Finely laminated buff argillaceous shale		80
	Fossils: *Hyolithes Billingsi* and *Ptychoparia Piochensis.*		
8.	Gray to bluish black compact limestone		18
9.	Buff arenaceous shales		64
10.	Compact cherty limestone		50
11.	Compact shaly sandstone in massive layers		40
12.	Hard siliceous gray limestone, almost quartz at base		12
13.	Yellow to buff sandy shale		70
14.	Bluish black limestone		16
15.	Yellow to buff sandy shales		40
16.	Bluish black, hard, compact limestone		12
	Fragments of fossils.		
17.	Shaly sandstone in massive layers		52
18.	Gray arenaceous limestone		2
19.	(a) Buff sandy shale	40	
	(b) Gray arenaceous limestone	30	
	(c) Sandy, calcareous shale	3	
			73
20.	(a) Massive-bedded, bluish-gray limestone	200	
	Fragments of fossils.		
	(b) Compact gray siliceous limestone, almost quartzite in some places	400	
	(c) Bluish black, evenly bedded limestone	6	
			606

Strike N. 30° W., dip 10° E.

* U. S. Geol. Survey, Bull. No. 30, pp. 33, 34, 1886.

21. Buff to pinkish argillaceous shale, with fossils, and a few interbedded layers of limestone from 3 to 15 inches thick	125
Fossils: *Eocystites ?? longidactylus*, *Lingulella Ella*, *Kutorgina pannula*, *Hyolithes Billingsi*, *Ptychoparia Piochensis*, *Zacanthoides typicalis*, *Bathyuriscus Howelli* and *B. producta.*	
22. Massive-bedded, siliceous limestone; weathering rough and broken into great belts, 200 to 300 feet thick, by bands of color in light gray, dark lead to bluish black; on some of the cliff faces the weathered surface is reddish	1,570
23.* Bluish black limestone in massive strata, that break up into shaly layers on exposure to the weather. The latter feature is less distinct 850 feet up, and the limestone becomes more siliceous, with occasional shaly beds	1,430
Fossils: Near the summit specimens were found that are referred to *Ptychoparia minor.*	

SUMMARY OF SECTION.

1. Quartzite	350
2. Limestone and shales (argillaceous and arenaceous)	1,450
3. Massive limestone	3,000
	4,800

At the horizon of Nos. 2 and 3 of the section, the Olenellus or Middle Cambrian fauna occurs; a fauna whose stratigraphic position is known in several sections. The next well-marked grouping of fossils occurs in No. 21, where, in the section and at a corresponding horizon in the Pioche section, the species mentioned in No. 21 were found. Of this fauna the two following species occur in the collection from Mt. Stephens, viz: *Zacanthoides spinosus* and *Bathyuriscus Howelli.* The same type of fauna occurs in the Cambrian section of the House range, at Antelope Spring, Western Utah, where, of the species found at Mt. Stephens, there occur: *Agnostus interstrictus* and *Olenoides Nevadensis.*

Acrotreta gemma is found in No. 2, in the Highland section, near Pioche, Nevada, and it ranges up into the Upper Cambrian, in the Eureka District. *Hyolithellus micans*, although a common Middle Cambrian species, has not been identified, heretofore, west of New York.

Of the eight species found at Mt. Stephens, six are stratigraphically located in the Cambrian system. Two species—*Ogygia ?? Klotzi* and *Ptychoparia Cordilleræ*—are unknown to me from any other locality.

* Quite a fauna occurs in 23, as found one mile farther south on the line of section.

The next superior fauna to the Olenoides of No. 21, is that occurring in No. 23, of the Highland section. It is of Upper Cambrian or Potsdam age, and contains: *Bellerophon antiquatus*, *Pleurotomaria* (3 undetermined species), *Hyolithes* (3 new species), *Dicellocephalus Pepinensis*, *Dicellocephalus* (type of *D. Minnesotensis*), *Dicellocephalus* sp., *Ptychoparia* (*Euloma?*) *dissimilis*, *Ptychoparia* sp.?, *Arethusina Americana*, *Illænurus* sp.?. Of this fauna two species are identical with those from the higher Potsdam fauna at Eureka, viz: *Ptychoparia* (*E.?*) *dissimilis* and *Arethusina? Americana*; and *Bellerophon antiquatus* and *Dicellocephalus Pepinensis* occur in the Upper Potsdam sandstone of Wisconsin. The presence of the Pleurotomaria-like shells and the species just mentioned correlates the fauna with that of the upper horizon of the Potsdam faunas of Wisconsin and Nevada.*

From the data mentioned I am led to the conclusion that the Mt. Stephens fauna described by Dr. Rominger should be referred to about the horizon of the upper portion of the Middle Cambrian fauna. This correlation, united with the discovery of the Olenellus fauna by Dr. George M. Dawson, in 1885, near Kicking Horse Pass, on the line of the Canadian Pacific railway, leads me to think that the Middle Cambrian fauna will be found to extend all along the western side of the great Keweenawan continental area, from Southern Nevada far into British America, and that that area will be found to belong to one geologic and faunal province of the Cambrian system.†

As Dr. Rominger has described nearly all the forms from Mt. Stephens as new to science it is necessary for me to review his work, since I have otherwise identified them in my work on the Middle Cambrian fauna.‡

He describes the new genus, Embolimus, and five new species of trilobites, viz: *Ogygia Klotzi*, *O. serrata*, *Embolimus spinosa*, *E. rotundata* and *Conocephalites Cordilleræ*. He also identifies *Monocephalus Salteri?* Billings, *Bathyurus?*, *Agnostus* ("compare *A. integer* Barr.") and the genera Orthis, Obolella, Kutorgina, Leptæna?, Metoptoma and Hyolithes.

Embolimus.—The generic name Embolimus was given by Westwood to a genus of Hymenoptera in 1833.§ It was spelled Embol*e*mus by Westwood and was corrected by Professor Agassiz in the Nomenclator Zoologicus

The first species named under this genus by Dr. Rominger, *Embolimus spinosa*, was described as *Olenoides spinosus* in

* Loc. cit., p. 35.

† This Journal, III, vol. xxxiii, pp. 139–157, 1886.

‡ U. S. Geol. Survey, Bull. No. 30, 1886.

§ Phil. Mag., II, 1833.

1886,* and the second species, *Embolimus rotundatus*, as *Bathyuriscus Howelli.*†

When studying the Georgia fauna, in 1885, I found that the genus Olenoides was probably the same as the genus Dorypyge of Dames.‡ Wishing more material for comparison I left all the species under the genus Olenoides. A large, fine species of the genus Olenoides was collected in the Cambrian shales of Northern Alabama, in 1886, which proved conclusively that Dorypyge was founded on a species congeneric with the type of Olenoides. I then recognized that the species *Olenoides typicalis*, *O. spinosus*, *O. levis* and *O. flagricaudatus* formed a distinct generic group, which I was having drawings prepared to illustrate when Dr. Rominger's paper appeared. As the generic name proposed by him is preoccupied, I now propose the name Zacanthoides, including in it: *Z. typicalis*, *Z. spinosus*, *Z. levis* and *Z. flagricaudatus.* The species remaining under Olenoides are *O. Nevadensis*, *O. Marcoui*, *O. quadriceps* and *O. Wasatchensis.*

By a comparison of specimens I found that *Embolimus spinosa* Rom.=*Zacanthoides spinosus* Walcott, *Embolimus rotundata* Rom.=*Bathyuriscus Howelli* Walcott, *Ogygia serrata*=*Olenoides Nevadensis* Meek; and that *Conocephalites Cordilleræ* Rom. = *Ptychoparia Cordilleræ* Rom. (sp.), and *Ogygia ?? Klotzi* Rom. are new to the previously known Cambrian fauna.

Zacanthoides spinosus Walcott, 1886=*Embolimus spinosa* Rominger, 1887.—This is a strongly marked species and occurs at Pioche and Eureka, Nevada, and in the collections from Mt. Stephens.

Bathyuriscus Howelli Walcott, 1886§=*Embolimus rotundatus* Rominger, 1887.—In the type figure of this species one segment has been forced beneath the head, a fact that was overlooked in the original specimen. A comparison of specimens from Mt. Stephens with the type from Pioche, Nevada, shows them to be specifically identical.

Olenoides Nevadensis Meek=*Ogygia serrata* Rominger.—This fine species is the type of the genus Olenoides; and a comparison of the specimens from Mt. Stephens with the type specimens leaves no doubt in my mind as to their specific identity.

Ptychoparia Cordilleræ Rominger.—A specimen of this species, 23^{mm} in length, has nineteen segments in the thorax and in this respect is similar to *Ptychoparia Piochensis* Walcott, from the same horizon, at Pioche, Nevada. The head,

* U. S. Geol. Survey, Bull. No. 30, p. 184, Plate XXV, fig. 6.
† Loc. cit., p. 216, Plate XXX, figs. 2, 2a.
‡ Loc. cit., p. 221.
§ U. S. Geol. Survey, Bull. No. 30, Plate XXX, fig. 2.

however, is unlike that of the latter, being more closely related to that of *P. Kingi* Meek.

Ogygia? Klotzi Rominger.—This is a fine, large species, and distinct from any known to me from the Cambrian terrane. It is more a type of the second fauna than of the first; and its reference to the genus Ogygia is in accord with its general characters. It differs, however, in the important feature of having an ocular ridge extending from the anterior margin of the eye to the dorsal furrow, beside the glabella. The palpebral lobe is also more narrow and elongate than the eye of most species referred to Ogygia. All other parts of the head, thorax and pygidium relate it more closely to Ogygia than to any other genus. The oldest known species of the genus, *O. Selwyni* Salter, from the Arenig terrane of Wales, is not quite so closely related in form to *O.? Klotzi* as to the *O. Buchi* from the Llandeilo terrane.

It is unusual that a genus, showing so little variation from Ogygia, occurs at a much lower horizon in an area separated by over 5,000 miles, from the area where the species of Ogygia flourished at a later period in geologic history.

Agnostus interstrictus White=*Agnostus* Rominger.—This species of Agnostus is very abundant at Antelope Spring, Utah, where it is associated with *Olenoides Nevadensis*, as at Mt. Stephens.

Acrotreta gemma Billings.—The broad, low form of this species occurs compressed in the shaly slate. The specimens at hand are poor, but they appear to be identical with those from the Cambrian horizon at Pioche, Nevada.

Kutorgina Prospectensis Walcott?.—A fragment of a species of Kutorgina, closely related to *K. Prospectensis*, occurs on the slate in association with *Ptychoparia Cordilleræ*. It is not improbable that it represents a new species.

Hyolithellus micans Billings.—Black, shiny, concentrically striated or smooth, compressed tubes occur in the shale with the trilobites, that appear to be identical with *H. micans* of the Middle Cambrian fauna of New York, Vermont and Canada. The "slender stems," mentioned by Dr. Rominger, may be the same as the slender shells of this species which appear like compressed stems formed of shiny carbonaceous matter.

It is doubtful what the specimen identified as *Menocephalus Salteri?* is. It may be the young of *Bathyuriscus Howelli*. The specimen figured as Bathyurus? is too badly defined to identify it. It certainly does not belong to the genus Bathyurus. Of the remaining genera mentioned by Dr. Rominger I do not find any traces in the material before me with the exception of a fragment of a species of Orthis.

ART. XVII.—*History of Changes in the Mt. Loa Craters;* by JAMES D. DANA.

[Continued from page 112.]

RELATIONS OF KILAUEA TO MT. LOA.

THE position of Kilauea "on the flanks of Mt. Loa," 9500 feet below the level of the summit, plainly suggests the idea of its later and dependent origin. If the two were begun at the same time, why, it is naturally asked, should not Kilauea have approximately the same size as Mt. Loa? With the same time to grow in, and a distance between the two nearly equal to that between Kea and Loa, and a crater as large and still active, would it have stopped at less than one-third the height and have raised its summit only 300 feet, at the best, above the Mt. Loa slopes?

Several of the islands, Oahu, Molokai, Maui, and perhaps also Kauai, consist of two volcanoes united at base, or are volcanically twins; and Hawaii is a double twin, one couplet consisting of Kohala and Kea, and the other of Hualalai and Loa, *provided* Kilauea is subordinate to Mt. Loa. In all the twins the *eastern* of the two combined volcanic mountains is the larger. But Kilauea, although the eastern on Hawaii and the easternmost of the whole group, is one of the smallest. The greater size of the eastern volcano in a couplet has come from its continuing longer in action; and this is proved not simply by the size, but also by the evidence of long extinction, and therefore long exposure to denuding agents, in the western mountain; that is by the depth and extent of the valleys of erosion, the time-marks, over it.* There is other evidence also

* As this evidence of the lapse of time is important, I here cite a few sentences from the chapter in my Exploring Expedition Geological Report, on the "Origin of the Valleys and Ridges of the Pacific Islands," pp. 379–392.

"Mount Loa, whose sides are still flooded with lavas at intervals, has but one or two streamlets over all its slopes, and the surface has none of the deep valleys common about other summits. Volcanic action has had a smoothing effect, and by its continuation to this time, the waters have had scarcely a chance to make a beginning in denudation. Mount Kea, which has been extinct for a long period, has a succession of valleys on its windward or rainy side which are several hundred feet deep at the coast and gradually diminish upward, extending in general about half or two-thirds of the way to the summit. But to westward it has dry declivities, which are comparatively even at base, with little running water. A direct connection is thus evinced between a windward exposure and the existence of valleys. And we observe also that the time since volcanic action ceased is approximately or relatively indicated; for it has been long enough for the valleys to have advanced only part way to the summit. Degradation from running water would of course commence on such slopes [windward slopes] at the foot of the mountain, where the waters are necessarily more abundant and more powerful in denuding action, in consequence of their gradual accumulation on their descent.

"Haleakala, or eastern Maui, offers the same facts as Mount Kea, indicating the same relation between the features of the surface and the climate of the dif-

in the fact that the slopes of the western of the mountains in each twin island are partly buried by the more recent lavas of the eastern—Kohala by those of Kea, western Oahu by those of eastern.* The order in time of extinction thus derived, which my Report presents, is as follows:

1. Kauai.
2. Southwest Oahu.
3. Western Maui.
4. Kohala, on Northwest Hawaii.
5. Northeast Oahu.
6. East Maui.
7. Mt. Kea, Hawaii.
8. Mt. Hualalai, Hawaii.
9. Mt. Loa and Kilauea.

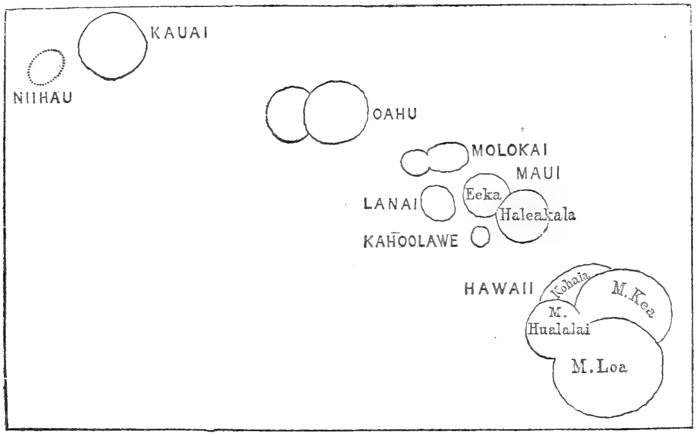
ferent sides of the island. On eastern Oahu the valleys are much more extensive; yet still the slopes of the original mountain-cone may be in part distinguished. And thus we are gradually led to Kauai, where the valleys are very profound and the former slopes can hardly be made out. The facts are so progressive in character that we must attribute all equally to the running water of the land. The valleys of Mount Kea, extending some thousands of feet up its sides, sustain us in saying that time only is required for explaining the existence of any similar valleys in the Pacific. As in Tahiti, these valleys in general radiate from the centre, that is, take the direction of the former slopes; they often commence at the central summits and terminate at the sea-level instead of continuing beneath it." (pp. 384, 385.)

"With literal truth, therefore, we may speak of the valleys of the Pacific islands as the furrowings of time and read in them marks of age. We also learn how completely the features of an island may be obliterated by this simple process, and even a cluster of peaks like Orohena, Pitohiti and Aorai of Tahiti, be derived from a simple volcanic dome or cone. Mt. Loa alone contains within itself the material from which an island like Tahiti might be modelled that should have nearly twice its height and four times the geographical extent" (p. 391.)

"We need add little in this place on the capabilities of running water after the statement, based on mathematics, that the transporting power varies as the sixth power of the velocity. If we remember that these mountain streams at times increase their violence a million-fold when the rains swell the waters to a flood, all incredulity on this point must be removed." "There is everything favorable for degradation which can exist in a land of perpetual summer; and there is a full balance against the frosts of colder regions in the exuberance of vegetable life, since it occasions rapid decomposition of the surface, covering even the face of a precipice with a thick layer of altered rock, and with spots of soil wherever there is a chink or shelf for its lodgement. The traveller ascending a valley on one of these islands on a summer day, when the streams are reduced to a mere rill which half the time burrows out of sight, seeing the rich foliage around, vines and flowers in profusion covering the declivities and festooning the trees, and observing scarcely a bare rock or stone excepting a few, it may be, along the bottom of the gorge, might naturally inquire with some degree of wonder, Where are the mighty agents which have channeled the lofty mountains to their base? But though silent, the agents are still on every hand at work: decomposition is in slow but constant progress; and the percolating waters are acting internally if not at the surface. Moreover, at another season, he would find the scene changed to one of noisy waters careering along over rocks and plunging down heights with frightful velocity, and then the power of the stream would not be disputed." (p 389.)

* The wonderful valleys of Kohala are given on the map of Hawaii, making Plate 1 of this volume. They are some of the deepest, most abrupt, and most beautiful in the islands, and are well described in Miss Bird's Six Months in the Sandwich Islands. Subsidence may have been concerned in the origin of part of them.

Here again the system seems to require that Kilauea should be made an appendage to Mt. Loa. I reproduce here from my Report the cut drawn to show these relations of the constituent volcanoes. In this diagram Kea and Hualalai are made to spread too far over Kohala, the central region of which should have been left uncovered; but the general idea conveyed is I believe correct.



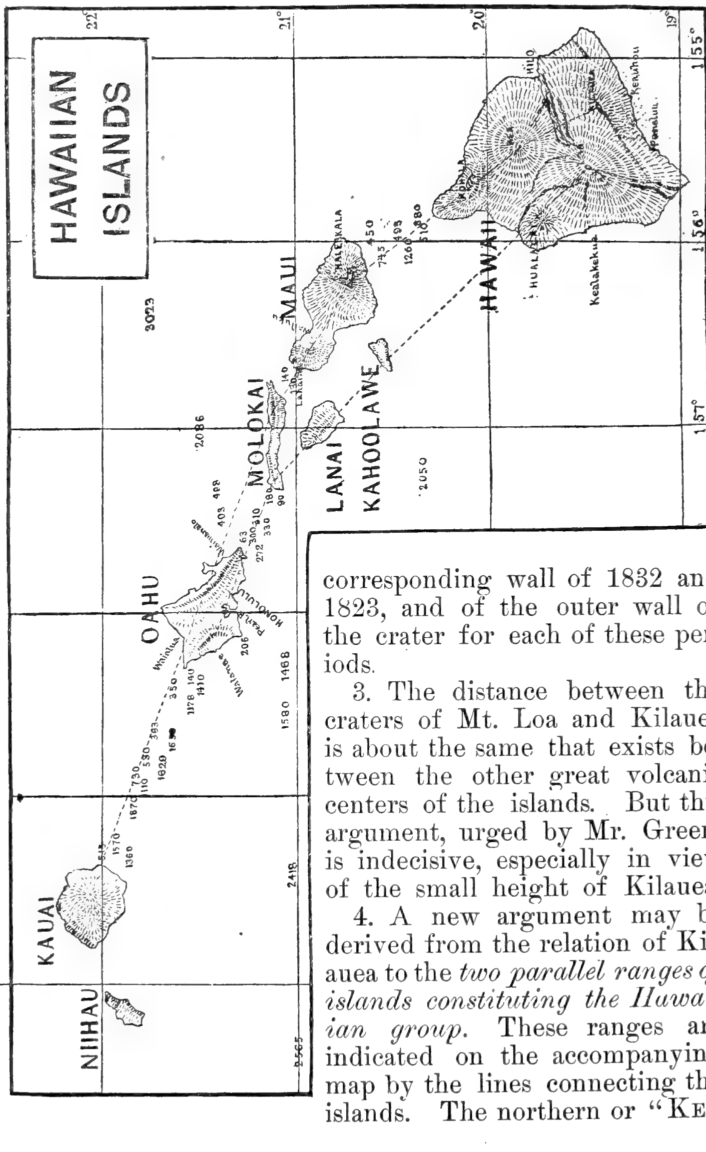
On these grounds, I concluded, in 1840, that Kilauea originated over a great fissure made at some Mt. Loa eruption.

This conclusion is not accepted in the report of Mr. W. T. Brigham, Captain C. E. Dutton, or Mr. W. L. Green.

1. The apparent independence of action in Kilauea is one of the opposing arguments; and it is a strong one. There is commonly no sympathy in their movements, although both have craters of unusual magnitude which are in frequent eruption and essentially in continuous activity; and although the open vent of Kilauea with its boiling lavas is but 3600 feet above the sea-level (in 1840 but 3000 feet) against 12,900 for the Mt. Loa crater. They have had some nearly simultaneous eruptions; but the larger part of the greater eruptions of Mt. Loa have taken place while the lava-lakes of Kilauea were in a state of undisturbed ebullition. There was remarkable harmony of action in the earthquake eruptions of the two in 1868; but it has been shown that the earthquakes which set off Kilauea were of Mt. Loa origin, made through Mt. Loa fires, and having their centre over thirty miles distant from Kilauea beneath the Mt. Loa slopes; and this harmonious action therefore does not indicate much sympathy between the two fiery neighbors after all.

2. In August, 1887, my examination of the walls of Kilauea

on the side toward the summit of Mt. Loa resulted in discovering no great dikes or other signs of former dependence on Mt. Loa. This evidence is not of great value, because the wall now exposed to view may be far inside of the wall of the greater original crater, just as the wall of the "lower pit" of 1840, which was in general without dikes, was inside of the



corresponding wall of 1832 and 1823, and of the outer wall of the crater for each of these periods.

3. The distance between the craters of Mt. Loa and Kilauea is about the same that exists between the other great volcanic centers of the islands. But this argument, urged by Mr. Green, is indecisive, especially in view of the small height of Kilauea.

4. A new argument may be derived from the relation of Kilauea to the *two parallel ranges of islands constituting the Hawaiian group.* These ranges are indicated on the accompanying map by the lines connecting the islands. The northern or "Kea

range," as I call it in my Expedition Report, includes northeastern Oahu, eastern Molokai, eastern and western Maui, and, on Hawaii, Kohala and Kea; the *southern* or "LOA range" comprises southwestern Oahu, western Molokai, Lanai, Kahoolawe, Mt. Hualalai and Mt. Loa, "with Lua Pele [or Kilauea] on the flanks of Mt. Loa." The Loa and Kea ranges have a mean trend of about S. 60° E. To the eastward the line of each range inclines increasingly to the southward. The northern, in its course from Maui through Kohala to the summit of Kea, becomes S. 45° E. in trend; and the southern from Kahoolawe to Hualalai and the summit of Mt. Loa has nearly the same course.

Now the line of the northern or Kea range, if continued on with only a little more southing, strikes Kilauea; while that of the southern points southward far away from it. *Kilauea appears, therefore, to belong to the Kea or northern range* and not to the Loa or southern; and if so, it is not an appendage to the latter, or to Mt. Loa, one of its volcanoes.

There is seemingly a "clincher" to this argument. The great craters are generally situated over the intersection of two fissures, one of which is the course of the range of islands and the other transverse to it, as stated by Mr. J. M. Alexander.* Now the line of the Kea range strikes Kilauea very nearly at right angles to its longer diameter in accordance with this rule. Further, the line of the Loa range, or better a line from the summit of Hualalai, strikes Mt. Loa precisely in the same way. This coincidence, which the map well shows, seems therefore to prove that Kilauea belongs to the Kea range and not to the Loa. The substitution of a line from Hualalai for that from Kahoolawe is reasonable, because the fissures over which the Hawaiian volcanoes were formed were probably independent for each island, though conforming to the general system. The summits of Kea and Loa are corresponding points in the two ranges, and Kilauea is an advance of one stage beyond Kea in the Kea range; it is owing to this that the longer diameters of the Loa crater and Kilauea make an angle with one another of about 32°. It is interesting to note, also, that the longer diameter of the crater of Mt Loa, or especially its southern half, points to the top of Mt. Kea; and that a line from Loa to Kea is nearly parallel to one between Hualalai and Kohala; so that the parallelogram enclosed has angles nearly of 70° and 110°.†

* This volume, page 38.

† Mr. W. L. Green, in his "Vestiges of the Molten Globe," brings forward a theory for the origin of the general features of the globe, which supposes its deformation from contraction on cooling to have developed feature lines crossing at angles of 60°—a "tetrahedral symmetry"—and, subordinately to these other

Notwithstanding the independence of Kilauea, there may still at times be evidence of some sympathy; for the two great active lava-columns are only twenty miles apart.

The evidence does not make it certain, however, that Kilauea originated as early in the history of Hawaii as either Kea or Loa; for the original fracture extending in that direction from Kea may at first have been sufficient only to let out a flood of lavas, and subsequently have been further opened and crossed by a greater fissure, so as to produce over it the permanent Kilauea vent.

5. Whatever the fact as to the relations of Kilauea and Mt. Loa, I believe they still sustain my old conclusion that volcanoes are not safety-valves;‡ for "if while Kilauea is open on the flanks of Mount Loa, lavas still rise and are poured out at an elevation of 10,000 feet above it, Kilauea is no safety-valve even for the area covered by the single mountain. Volcanoes are indexes of danger; they point out the portions of the globe which are most subject to earthquakes." The safer place is somewhere else. And among volcanic mountains, one that is really dead is a preferable neighbor to the volcano that has been smouldering from time immemorial. For the emission of heat by hot springs, geysers or fumaroles within a dozen miles is pretty good evidence, as at Tarawera, New Zealand, that liquid rock is at no very great depth below; too deep to receive from descending waters the moisture that may contribute energy to the fires and produce volcanic activity, but not too deep to be opened on an extreme emergency, so as to give entrance to a flood of waters for the most terrific of eruptions.

CONTRAST BETWEEN VOLCANOES OF THE MT. LOA AND VESUVIUS TYPES.

The marked contrast between volcanoes of the Mt. Loa and Vesuvius types based on the liquidity of the lava, making Mt. Loa discharges to be almost solely outflows, and those of Vesuvius, both upthrows of cinders and outflows of lava, has been sufficiently explained (xxxv, 28). With this exception, the contrast as to their eruptions, as well as to their ordinary action, is far less than is generally supposed.

lines at right angles to the sides of the triangle. His map of the Hawaiian Islands, which is covered with triangles, represents one of these lines as meridional, and one accordant, consequently, with the mean trend of the group, or nearly so. On page 147 of his work, it is stated that confirmation of his hypothesis is seen in the fact "that the direction of the longer axis of the elliptical craters of Mokuaweoweo and Kilauea is N. 30° E." But the facts appear to be that the longer axes of the two craters diverge 32° in direction, and that of Kilauea has nearly the course N. 52° E. Moreover, the trend of the island volcanoes of the group varies greatly in going from one end of the range to the other, and in this the Hawaiian is like other ranges over the ocean.

‡ Expl. Exped. Report, p. 221.

There is no reason to regard the forces as different in kind or mode of action. If the outside waters gain slow access, at depths below, to the lavas for the ordinary action of a volcano in Hawaii, they can at Vesuvius; and the force from the escaping vapors that, in this ordinary action, will make jets of lava of 30 feet to 600 feet, will make jets of cinders of far greater height. Moreover, as the erupting force at Mt. Loa in non-explosive eruptions, is not due to vapors inside the lava-column, since it does its chief fracturing part way down and sometimes far down the mountain instead of about the summit, and causes a quiet condition in the crater instead of violent action, so it is essentially at Vesuvius. In *explosive* eruptions at Vesuvius, on the contrary, the explosive force is due to vapor-generation inside of the lava-cauldron, the projectile action being vastly increased, as at Tarawera in 1886 and Krakatoa in 1883 (page 104).

As the observations at Vesuvius of Scacchi and others have shown (and my own two visits to Vesuvius, one just before an eruption, enable me to appreciate) high-lava mark in the volcano, or that of readiness for a discharge, is attained in the same way essentially as in Kilauea. After a down-plunge following an eruption (as a result of the undermining), leaving the crater hundreds of feet in depth and the upper extremity of the lava-column at a still lower level, work again soon commences, provided the lava-column was not so profoundly cooled off by the aggressive waters and vapor-generating as to be left too deeply buried. For a while the fractures in the bottom of the crater emit only vapors. Later, projectile action begins at one or more points, making conical cinder-deposits by the pericentric action, with now and then an addition to the inside accumulations from small outflows of lava about the bases of the cones or from their vents. The throws of cinders and flows of lava are kept up at irregular intervals, and the level of the floor rises. After the height within has become much increased, small fissures occasionally open through the outside slopes and let out some lava; but the ejections are mostly retained inside except in the later period of progress when some of the high-thrown cinders may fall over the outside of the mountain or drift away with the wind. Years pass; and finally the crater's bottom, bearing a large cinder cone, or more than one, reaches that high level in which it becomes actually the summit-plain of Vesuvius, and the fires are visible in the cracks of the plain because the liquid lavas are not far below it.* High-lava mark is thus attained and an eruption may be at hand. Severe earthquakes are not needed in the work any more than at Kilauea.

* I may refer here to a cut representing Vesuvius in this condition in my Text-book of Geology, made from my sketch in 1834, and to a paper in this Journal for 1835.

How far the ascensive force in the lava-column contributes to the change of level in the floor of Vesuvius nobody knows. The question has hitherto hardly been considered. It probably does its part, for, the liquid lava rises with the rising floor, following it closely.

With the column of liquid lava thus lengthened, making the mountain ready for a discharge, the danger of catastrophe is great for the same reasons as at Kilauea. But the danger is greater than there. It is greater because the forces from vapor-generation and hydrostatic pressure have a weaker mountain to deal with—one that has steeper sides and therefore thinner walls to the lava-cauldron, and walls that are partly cinder-made. It is greater because also of the nearness of the lava-column to the sea, the distance being only four miles, while in the case of Kilauea it is over nine miles and in Mt. Loa over twenty; so that at Vesuvius water from two sources, the sea and the land, is close by.

Causes that produce earthquakes may make a rent in the Vesuvian lava-conduit that will let in water for an *explosive* eruption; but usually it opens the way, as at Mt. Loa, for a comparatively quiet escape of lava, however disquieting the event may be to deluged villages.

The loss by upthrows and outflows tends to produce a sinking or down-plunge of the floor of the crater, and some fall of its walls to the new bottom, as in Kilauea. At the Kilauea eruption of 1886, the outflow drew off the lavas of a lava-lake half a mile in diameter; the crust of lava that covered the borders of the lake, along with portions of the walls, consequently sunk down, and the cavity or crater left by the discharge was half a mile across and between 500 and 600 feet in depth. This is little different from the ordinary event in Vesuvius, except that the loss by the discharge at Kilauea is almost solely by outflow, and no high, weak-sided cone surrounds the vent to suffer from the disaster. It is true that the Kilauea lava-lake in the eruption just referred to occupied only a small part of the great crater. But its diameter was as large as the lava cauldron of Vesuvius has been before any of its modern eruptions; and the movements in the lake were the same that would take place were all Kilauea one great lake.

Explosive eruptions might prove more disastrous to a Vesuvian cone than to one of massive Mt. Loa style; but not because the explosion has the power of blowing off the mountain's summit—which failed to happen at Tarawera in 1885 although the vent was closed and is not a possibility when the vent is an open one—but chiefly because a steep-sided mountain is likely to lose more in height than a broad lava-cone from the same amount of undermining.

We may hence conclude that (1) Vesuvius and Mt. Loa are instructive examples of the effects of the same volcanic forces and methods under different conditions as to rock materials and heat; and (2) *systematic study inside of craters between volcanic eruptions* is what the science most needs.

In another paper, the results of volcanic action will be further illustrated from observations made, the past year and earlier, in the islands of Maui and Oahu.

ART. XVIII.—*On the formation of deposits of Oxides of Manganese;* by F. P. DUNNINGTON.

IN explanation of the transfer of compounds of manganese, which has taken place in the formation of geological deposits, the only agency mentioned in works on chemical geology as taking prominent part is that of carbonated water, forming the soluble manganese bi-carbonate. Dr. Bischof remarks,* "With regard to the formation and alteration of manganese spar, the same relations obtain as in the case of iron spar." However, Fresenius has shown† that bi-carbonate of iron and of manganese are obtained under different conditions. There is possibly a hint of the formation of manganese sulphate given by Kersten,‡ but it is not definitely mentioned.

I propose in this article to call attention to the probability that manganese sulphate has taken a very important part in the formation of deposits of manganese ores.

Bunsen's analytic method for the valuation of manganese ores is based upon the fact that an acid solution of a ferrous salt will dissolve the higher oxides of manganese, with the formation of a corresponding amount of a ferric salt. Having observed the promptness with which such solutions are effected, I was led to make some examination of the action of similar solutions upon compact forms of oxide of manganese, and further to ascertain some of the conditions under which solutions of ferrous sulphate, ferric sulphate and manganese sulphate are decomposed. With this in view, the following experiments were made:

1st. There was prepared a solution of ferrous sulphate and sulphuric acid in such proportions as would result from the oxidation of iron pyrites and solution in 25 parts of water. In 500 c.c. of this solution, a lump of crystallized pyrolusite was suspended near the top of the liquid for 48 hours, resulting in

* Chem. and Phys. Geol., vol. i, p. 57, trans. Cav. Soc.
† Loc. cit., vol. iii, p. 531.
‡ Loc. cit., vol. i, p. 160.

dissolving a thickness of ·804 mm. (as calculated from the specific gravity of the mineral, area of the surface exposed and loss of weight); a rate of solution equivalent to 6 inches in one year.

2d. A lump of compact psilomelane was similarly suspended in the acid ferrous solution and a thickness of ·506 mm. was dissolved in 48 hours; equivalent to 3·78 inches in one year. In each of the foregoing experiments a corresponding amount (45 and 12 per cent of the total) of the ferrous salt was converted to ferric.

3d. A glass tube 3 cm. in diameter and 20 cm. in length, contracted at one end, was filled with a mixture of coarse powders of psilomelane, 75 grm., disintegrating pyrites (from Marienburg near Bonn), 100 grm. and glass. Through this tube two liters of water were allowed to percolate in the course of 24 hours, and in the liquid was found manganese sulphate, 7 grm., ferric sulphate, 1·45 grm. and sulphuric acid, 4·34 grm.

4th. Through the above filled tube, two liters more of water were similarly passed and this dissolved of manganese sulphate, ·154 grm., ferric sulphate, ·07 grm.

5th. Through the above filled tube, two liters more of water were passed, while a continuous current of air was drawn through the tube; this dissolved of manganese sulphate ·292 grm., with about ·07 grm. of ferric sulphate.

6th. The glass tube was then refilled, as at first, but using a bright granular pyrite (from Louisa Co., Va.). The current of air was kept up, and two liters of water, dropping at a uniform rate, were passed through the tube in the course of twenty-one days; this dissolved of manganese sulphate ·098 grm. and no iron, while a small amount of ferric hydrate was formed and remained in the tube.

7th. A neutral solution of ferrous sulphate digested *cold* with manganese carbonate, air being excluded, no change takes place; but when heated to 100° C. for two hours, considerable manganese sulphate and ferrous carbonate were formed.

8th. Ferric sulphate solution reacts immediately upon manganese carbonate, forming manganese sulphate, ferric hydrate and carbonic acid.

9th. By reason of the fact, which is familiar, that ferrous sulphate solution is rapidly oxidized when exposed to the air, we find that when it is in contact with manganese carbonate, in the presence of air, the manganese carbonate is decomposed, forming manganese sulphate, etc., as above.

10th. A neutral solution of ferrous sulphate with calcium carbonate, sealed in a tube under carbonic acid, was heated to 100° C. for two hours; mutual decomposition took place, forming ferrous carbonate and calcium sulphate.

11th. Ferric sulphate solution reacts immediately upon calcium carbonate, forming calcium sulphate, ferric hydrate and carbonic acid.

12th. Ferric sulphate solution digested cold or hot with powdered manganese oxide was not altered.

13th. Ferric sulphate solution was digested cold for nine days with sawdust and powdered psilomelane; considerable manganese sulphate was formed.

14th. Manganese sulphate solution is not altered by exposure to air, but when so exposed, and also in contact with calcium carbonate, manganese oxide is gradually formed.

15th. Manganese sulphate solution, digested cold with calcium carbonate in a sealed tube, is not altered; when heated, it is feebly affected, a little manganese carbonate being formed.

In view of the foregoing observations and results, it appears possible that many deposits of manganese in calciferous rocks owe their formation to the action of solutions of sulphates, and possibly an illustration of such action is presented in the manganese deposits of Crimora, Augusta Co., Va., which occur under the following conditions.

In the Shenandoah Valley, the upper portion of formation I (Rogers) is composed of shales which are well decomposed to a great depth, interspersed with remaining calciferous ledges, and as they pass westward these alternate with, and are succeeded by, ledges of siliceous limestone. In these decomposed shales, we find pure neutral iron ores, free from manganese, and associated with them there are manganiferous limonites and also psilomelane of high grade, frequently appearing to have grown in similar condition, and sometimes the same mass is composed in part of manganese and in part of limonite. South of the Potomac, no pyrites is visible in these shales, possibly owing to the great depth to which they have been decomposed; but at Harper's Ferry, the iron ore lying in the same geological horizon has been worked down until compact pyrites has been reached. The presence of the pyrites in the latter renders it probable that it did exist extensively in the shales above described.

Assuming that pyrites did thus exist, generally distributed, we might expect a deposition of ores to have occurred in some such manner as the following.

Where pyrites has been deposited and subsequently has been exposed by reason of erosion, the outcrop is gradually converted into limonite by weathering, and the acid solution of ferrous sulphate which sinks into the underlying deposits, must carry with it all manganese associated with the decomposing sulphide, also that in any disintegrating silicates and

such as is distributed through the soil in the form of oxides or carbonate. As this solution is exposed to the air or meets with calcium carbonate, it will lose iron, the calcium carbonate removing all free acid, and an excess of the latter rock will remove all iron from the solution, as ferrous carbonate, while the manganese sulphate would remain in solution until exposed to both air and calcium carbonate at the same time. Of course, the deposition of either iron or manganese oxides from solutions of sulphates by action of calcium carbonate results in the formation of calcium sulphate, which is carried away in solution in the water; so that the calcium is either wholly or in part removed from the strata in which such deposits are formed, and we would expect to find only occasional ledges remaining as we find in the vicinity of the Crimora deposit.

An additional argument for the transportation of manganese as sulphate rather than bi-carbonate lies in the great depth at which some deposits of manganese are found; for the bi-carbonate would deposit oxide of manganese, wherever exposed to the air, while the sulphate would, where calcium carbonate had been previously removed, need to penetrate to a greater depth before reaching the conditions for its deposition. Moreover, the fact of the concentration of the manganese in masses rather than its general distribution through the decomposed shale would indicate that some condition additional to the exposure to oxygen had determined its deposition.

It is also to be noted that after all sulphur is removed from the overlying strata, the subsequent action of carbonated water might then occasion some transfer and redistribution of the previously formed deposits.

University of Virginia, April 6th, 1888.

Art. XIX.—*Maxwell's Theory of the Viscosity of Solids and Certain Features of its Physical Verification*;* by Carl Barus.

1. The viscosity of solids has been theoretically discussed in the memoirs of O. E. Meyer, Boltzmann, Neesen, Warburg, Maxwell, and Butcher. Views of a distinctly theoretical kind have also been given by Weber and Kohlrausch, and more recently by Nissen. In almost all cases, excepting alone Butcher's† work, which formulates the theory of Maxwell,‡ the problem has been approached from distinct points of view.

* Communicated by permission of the Director. This paper makes up a chapter of a U. S. G. S. Bulletin on the Viscosity of Solids, which will form the second contribution to certain experiments on the Physical Constants of Rocks, following a plan devised by Mr. Clarence King.

† Butcher: Proc. Lond. Math. Soc., iii, 1878.

‡ Maxwell: "Constitution of Bodies," Encyclop. Brit., 9th ed., p. 310, 1876.

Despite the diversity of methods of discussion and the elaboration of evidence, the results do not in any case so fully represent the phenomenon as to lead to general acquiescence in one elementary physical hypothesis. Boltzmann's theory is perhaps the most powerful and is elegantly worked out; but it is purely mathematical in character. Maxwell's theory has the broadest physical basis, although left by its author in shape merely of a terse verbal sketch.

Now it seems to me, if indeed I may venture any assertion, that Maxwell's theory is a version of Williamson's* theory of etherification, and of Clausius's† theory of electrolysis. The transition made is from unstable groupings of atoms to unstable groupings of molecules. But preserving minutely all the essentials of Maxwell's argument, the experiments of this paper permit me to go one step further, by which viscosity is a phenomenon evoked by certain changes of molecular structure, the inherent nature of which is ultimately chemical. I say chemical because if molecular break up occur, cardinal questions at once arise as to the manner of removal of the debris; and the phenomenon thus depends not only on the past history, but on the immediate future history of the typical mean configuration. The analogy of the three theories is very close, so that they admit of generic classification. They are examples of the invasion of statistical method into liquid and solid molecular kinetics.

The behavior of steel when regarded as a viscous solid and in the light of known facts,‡ is convincingly in favor of the view to be advocated; and it was the direct bearing of some of the results on Clausius's theory of electrolysis, that led me to suspect a chemical explanation,§ before I became aware of the existence of Maxwell's article. To show how clearly Maxwell's theory interprets the complex and almost anomalous phenomena of viscosity exhibited by steel, is the chief endeavor of the present paper; but I shall also add other matter.

2. It is desirable to pass in brief review the divers hypotheses on the nature of solid viscosity to which I have referred.

O. E. Meyer's‖ theory is the earliest and most direct. It discusses the action of elastic forces in a medium of imperfect elasticity, and develops formulæ to express the diminution of

* Williamson: Ann. d. Chem. u. Pharm., lxxvii, p. 37, 1851.

† Clausius: Pogg. App., c, p. 353, 1857; ibid., ci, p. 338, 1857.

‡ I refer in particular to the work of Dr. Strouhal and myself. These papers, systematically discussed and enlarged, are embodied with much new matter in the Bulletins of the U. S. Geological Survey, viz: Bull. No. 14, pp. 1 to 226, 1885; Bull. No. 27 pp. 30 to 61, 1886; Bull. No. 35, pp. 11 to 60, 1886; Bull. No. 42, pp. 98 to 131, 1887. Other references are given in the text.

§ This Journal, III, xxxiii, p. 28, 1887. It is much to be regretted that Maxwell's theory was published out of the line of a physicist's usual routine reading.

‖ Meyer: Pogg. Ann., cli, p. 108, 1874.

stress in virtue of the occurrence of internal friction.* The results to which Meyer's formula eventually leads are incomplete and were not fully verified by subsequent experiment. The theory is therefore sharply antagonized by Boltzmann,† by Streintz,‡ and by Kohlrausch.§ In a later paper Meyer‖ partially assents to these adverse views, acknowledging that the theory does not reproduce the phenomenon actually observed. It also fails, as Kohlrausch (l. c.) pointed out, in predicting an insufficiently slow time of occurrence. After giving reasons for dissenting from Boltzmann's and from Neesen's hypotheses, Meyer proceeds to partially develop an older idea of Weber's.¶ This physicist referred viscosity in solids, to partial molecular rotation, a view adopted by Kohlrausch,** by whom it has been more clearly interpreted. The rotations underlying Weber's phenomenon are considered identical with the rotations of molecule postulated by Clausius†† in discussing shear. Following Meyer and others, "elastische Nachwirkung" is a possible occurrence in liquids.

Boltzmann's‡‡ theory, amplifying deductions of Lamy and of Clebsch, is based on the assumption that the elastic forces are dependent not only on the present but on the preceding deformations of the body. The effect of earlier states of stress on the existing stress diminishes with the intervening time but is independent of intervening states of stress. Different viscous deformations are superposable. Boltzmann's theory, therefore, presupposes the phenomenon§§ and brings the laws of viscosity tersely into formulæ. If ω is an interval of time reckoned back from $t-\omega$, when the strain $\theta_{t-\omega}$ existed, then Boltzmann's law may be clearly exhibited in its application to the problem of vibration of a viscous solid. Given a wire of the solid of length l and radius R. Let the upper end be fixed, and the lower end be attached to a heavy bob, whose moment of enertia for the given conditions is K. Then the equation of motion is (slow oscillation presupposed)

* Following the usage of the term by Navier, Cauchy, Poisson, St. Venant, Stokes, Stefan. Cf. Meyer, l. c.

† Boltzmann: Pogg. Ann, Ergänzb. vii, p. 624, 1876.

‡ Streintz: Pogg. Ann., clv, p. 588, 1875; ibid., cliii, p. 405, 1874.

§ Kohlrausch: Pogg. Ann., clx, p. 225, 1877.

‖ Meyer: Wied. Ann, iv, p. 249. 1878.

¶ Weber: Pogg. Ann., xxxiv, p. 247, 1835; ibid., liv, p. 1, 1841.

** Kohlrausch: Pogg. Ann., cxxviii, p. 413, 1866: cf. also ibid., cxix, p. 337, 1863.

†† "Wenn ein solcher Körper fremden Kräften unterworfen wird, die von verschiedenen Seiten ungleich unf ihn wirken, also z. B. nach einer Dimension gedehnt wird, während er nach anderen Dimensionen frei bleibt oder gar zusammengedrückt wird, dann die Moleküle neben ihrer Verschiebung sich auch etwas drehen können, indem sie in Bezug auf ihre Kraftrichtung den ungleichen Spannungen etwas folgen. . . . " Pogg. Ann., lxxvi, p. 66, 1849.

‡‡ Boltzmann: Pogg. Ann., Ergänzb., vii, p. 624, 1876.

§§ Kohlrausch: Pogg. Ann., clx, p. 227, 1877.

$$D-K\frac{d^2\theta_t}{dt^2}=\frac{\pi R^4}{2l}\left\{\mu\theta_t\int_0^\infty \psi(\omega)\,\theta_{t-\omega}\,d\omega\right\},$$

where D is the moment of the applied couple, μ Lamy's constant and ψ some function of ω.

Replying to Meyer's critique that a theory of this kind is at variance with the present state of knowledge in atomistics, Boltzmann* disclaims all present purpose to connect his theory with definite physical hypotheses. He points out, however, that the assumed dependence of the existing strain on foregoing deformations, is easily justified when the simultaneous changes of molecular configuration are taken into account: for it is not necessary to suppose that the elastic forces, *as such*, have any dependence on the preëxisting stress. The changes of configuration in question are closely similar to Maxwell's, so that in this respect, Boltzmann's theory may be looked upon as one form of mathematical development of Maxwell's physical hypothesis. I may add that Boltzmann tested his theory with data of Kohlrausch, Neesen, and Streintz. A special series of experiments subsequently undertaken by Kohlrausch† give additional strength to Boltzmann's deductions. The theory does not, however, predict permanent set.

A theory similar to Boltzmann's, but atomistic in character, is due to Neesen.‡ It also assumes the occurrence of solid viscosity. Neesen distinguishes the forces producing and retarding motion and the final purely elastic forces which obtain when viscous motion has subsided. Neesen practically postulates a change in the constants of elasticity. Warburg§ objects to Neesen's deductions because they contain no reference to the form of the molecule. Meyer (l. c.) fails to find in it definite causal relations to the observed viscous motion.

Braun's‖ research, though largely experimental in character, deserves mention here, because of special light which it throws on the superposition of different viscous deformations. Excepting in glass, he finds that these molecular motions do not take place independently of each other. He concludes that elastic and viscous deformations owe their occurrence to forces of different origin, and he refers viscous motion to the partial rotations postulated by Weber and Kohlrausch.

Warburg,¶ following out the suggestions contained in Braun's results, formulates a new theory in which viscosity is

* Boltzmann: Wied. Ann., v, p. 430, 1878.
† Kohlrausch: Pogg. Ann., clx, p. 225, 1877.
‡ Neesen: Pogg. Ann., clvii, p. 579, 1876.
§ Warburg: Wied. Ann., iv, p. 233, 1878.
‖ Braun: Pogg. Ann., clix, p. 337, 1876; cf. Kohlrausch: Pogg. Ann., clx, p. 227, 1877.
¶ Warburg: Wied. Ann., iv, p. 232, 1878.

the result of partial rotations of molecules of a form other than spherical.

Nissen's* theory is unique. He considers the ether in the space surrounding the body, in its relations to the ether within the intermolecular spaces of the body; and he bases his theory on the conditions under which the external ether enters the said intermolecular spaces, when the body is deformed by stress. He thus obtains both a time and a thermal effect In many respects this curious theory seems to me to anticipate Osborne Reynolds† in recognizing the importance of the "dilitancy" of a granular medium.

3. Maxwell's‡ theory would require more extended comment; but the terms in which his views are expressed are so precise, that it is impossible to abbreviate them. cf. § 9, 14. Aside from the remarks of the next paragraph, the ideas underlying Maxwell's theory have been given by many others, indeed by almost all the chief writers on solid viscosity; but Maxwell carries them through consistently to a complete theory.

I have stated that Maxwell's theory is the analogon of Clausius's theory of electrolysis. Where the latter uses "Theil molecüle" and electromotive force to effect chemical decomposition, Maxwell has unstable configurations and stress available to produce permanent deformation. In Clausius's case the number of decomposable molecule (i. e. unstable configurations as regards the action of electromotive force), in any given case of actual electrolysis, is practically infinite. This corresponds to Maxwell's viscous fluid, hard or soft. In a viscous solid, molecular configurations are present in all degrees of stability, with a sufficient preponderance of stable configuration to constitute a solid framework. The relative number of unstable configurations varies with the viscosity of the material. If, therefore, I conceive the case of an electrolyte exhausting itself with respect to electrical conductivity, by the chemical decomposition induced by current, until conduction cease, I have the analogon of a solid which is reaching the limit of viscous deformation. cf. § 21.

From this analogy it follows that a solid (?) electrolyte is necessarily viscous; whereas a viscous solid is only an electrolyte when the molecules break up into parts oppositely charged. Again, a viscous solid (?) is probably more viscous when undergoing electrolytic decomposition, than when no current passes through it.§ Experiments to the same effect can however be

* Nissen: Inaug. Dissert., Bonn, 1880. (Not accessible to me.)

† Reynolds: Phil. Mag., V, xx, p. 469, 1885.

‡ Maxwell: l. c., p. 311.

§ I have since been at some pains to verify this surmise, working with glass at 360°. But the experiments thus far are not decisive because the amount of current passing through glass is not only very small, but soon ceases entirely even in the case of thin-walled tubes (Warburg, Wied. Ann., xxi, p. 622).

made with greater facility, if the solid operated on is such that *special* instability of molecular configuration is superinduced by heat, instead of electrical action. Such a solid is hard steel, in which in addition to the ordinary thermal instability, what may be called a carburation instability of molecular configuration asserts itself, even at mean atmospheric temperatures, and in the homogeneous metal. Inasmuch therefore as the gist of Maxwell's theory is instability of configuration, it follows that the evidence which can be derived with reference to it, from hard steel, must be unique in character: for despite the extreme hardness and elasticity of tempered steel, instability of molecular configuration *demonstrably* exists,* and is distributed uniformly throughout the metal; moreover the number of unstable groups can be made to vary over an enormous range, at pleasure.

I must distinctly state, however, at the outset, that Maxwell limits his considerations to configurations of molecules. The responsibility of fusing Clausius's and Maxwell's theories rests with me. The step is dictated by the behavior of steel, in which the integrity of the molecule is certainly invaded without producing essential differences in the character or history of the viscous phenomena. § 13. I may note that the occurrence of chemical change makes the hypothesis verifiable.

4. Perhaps the experiments already made on the viscosity of steel† are a sufficient guaranty for the deductions of this paper; but as the above remarks clearly show, that data tending to throw light on the ultimate nature of viscosity are urgently called for, I shall add some further experimental results. To obtain these I made use of a perfected form of the apparatus described elsewhere.‡

For several purposes touched upon in the course of the present work, it is necessary to indicate the theory of the said apparatus more fully than was done in the earlier paper. Given a continuous straight steel wire of length L, to which a convenient rate of twist, τ, has been imparted. Consider two right sections whose distance apart is the unit of length, and let 2φ be the amount of viscous angular motion§ of the first relative to the second, during the given small time t, for the fixed rate of twist τ. To fix the ideas, let the wire be adjusted vertically, and provided with an index to register angular motion at a distance l' above the lower end. Then will the motion of the index due to viscous detorsion of two sections

* B. and S.: this Journal, III, xxxii, p. 276, 1886.

† B. and S.: this Journal, xxxii, p. 444, 1886; xxxiii, p. 20, 1887.

‡ B.: this Journal, xxxiv, p. 2, 1887.

§ In the earlier paper (xxxiv, p. 1) I erroneously called this quantity ϕ instead of 2ϕ; but this inadvertancy does not conflict with the purposes of the data there given.

whose position is x and whose distance apart is dx ($x > l$), during the time t be

$$d\psi = \frac{l}{x}\varphi dx.$$

For at every section the viscous motion is such, that if the contiguous parts immediately below the section slide in a given direction, the parts immediately above it slide, in equal amount, in the opposite direction. Again, of the two equal and opposite viscous motions which take place on any section, only the part nearest the index will influence it.

This premised, suppose furthermore that the parts of the wire below the index, the parts whose position is 0 to l', be kept at a given constant temperature and be of the same temper throughout. Let those parts also, of the wire above the index be of the same or any uniform temper; but let them be heated to different constant temperatures. Thus let the viscous detorsion between $x=0$ and $x=l'$ be typified by φ'; between $x=l'$ and $x=\beta$, by φ_3; between $x=\beta$ and $x=\alpha$ by φ; between $x=\alpha$ and $x=L$ by φ_1; in which the differences of φ_1, φ, φ_3 are evoked by differences of temperatures of the parts of the wire to which these data refer, whereas φ' may differ from all these by any increment of temper, as well as of temperature. Then the influence of the viscous detorsion in each of the parts in question, on the index whose position is $x=l'$, will be

$$l'\varphi_1\int_\alpha^L \frac{dx}{x},\quad l'\varphi\int_\beta^\alpha \frac{dx}{x},\quad l'\varphi_3\int_{l'}^\beta \frac{dx}{x},\quad l\varphi'\int_0^l \frac{dx}{L-x},$$

where $L-l'=l$. Hence the motion, ψ, of the index is

$$\psi=l'\left(\varphi_1 \ln\frac{L}{\alpha}+\varphi\ln\frac{\alpha}{\beta}+\varphi_3\ln\frac{\beta}{l'}\right)-l\varphi'\ln\frac{L}{l}.$$

Now if the experiment is so conducted that $\varphi_1=\varphi_3=\varphi'$, and $l=l'=\frac{1}{2}L$, which implies uniformity of temper throughout the wire from 0 to L, then

$$\psi=l(\varphi-\varphi')\ln\frac{\alpha}{\beta}$$

which suggests the most convenient method of experiment. If it is possible to heat the upper wire uniformly throughout its length, this equation takes the form $\psi=l\,(\varphi-\varphi')\ln 2$. If φ' is negligible relatively to φ, this method leads to absolute results.

There is another case which facilitates experiment. Let $\varphi_1=\varphi_3$, $\varphi=0$, $l=l'$. Then

$$\psi=l\varphi_1\ln 2+l(\varphi-\varphi_1)\ln\frac{\alpha}{\beta}.$$

If the behavior of the wires for $\varphi=\varphi_1$ (i. e. for the case in which the upper wire has the uniform temperature correspond-

ing to φ_1) be known, this equation is similar to the preceding. In general and intermediate cases, correction members must be investigated.

If a series of detorsions φ be observed at $\theta°$, and another series, Φ, at $\Theta°$; if $\varphi=\varphi_0 F(\theta)$ and $\phi=n/2R$ (Gauss' method of angular measurement), then $\varphi_0(F(\Theta)-F(\theta))=(N-n)/RL\ln 2$, where R is the distance between mirror and scale in *cm* and where N and n are the scale parts (*cm*) corresponding to $\Theta°$ and $\theta°$, respectively. Hence the distance of the individual curves for Θ' and $\theta°$ apart varies directly as φ_0. This result, though simple enough, has special bearing on the text below.

5. The following tables exhibit the new results for steel. About twenty rods were examined. Table 1, after enumerating the rod ("No."), and stating the temperature at which it was annealed ("An.") from glass-hardness, gives the amount of twist, τ (radians), temporarily imparted per unit of length, and $2(\varphi+\varphi')$, the mean amount of viscous detorsion, in radians per unit of length, observed immediately after the end of the experiment. $2(\varphi+\varphi')$ is therefore the mean viscous effect of τ impressed on the system of two vertical wires. Hence $\tau+2(\varphi+\varphi')=2\pi/L$. Furthermore, θ' is the temperature of the lower wire, θ that of the upper wire, and $(\varphi-\varphi')/\tau$ (radians) is the amount of viscous detorsion, as observed at the index between the wires, at the time specified, per unit of τ. Regarding this differential quantity, which is the chief datum of the tables, it is merely necessary to call to mind that 2φ is the viscous detorsion, per unit of length of the upper wire, for the rate of twist τ; and $2\varphi'$ has the same signification relatively to the lower (normal) wire. The reference to the unit of τ is a convenience permissible when τ, as in the present work, has nearly the same value throughout.*

The normal wire, No. 7, with which all the other steel wires are compared, is annealed from hardness at 450°, and has been twisted back and forth till viscosity is practically unchanged by further twisting within the same limits. It is therefore in a state of extreme viscosity, and at the same time less liable to permanent set than a soft steel wire. Its dimensions are $l'=30^{cm}$, radius$=\rho=0{\cdot}0405^{cm}$, so that $l'=l$. The wire of unknown viscosity is examined at 20° (nearly), and immediately after at 100°. Two experiments are made at each temperature with τ alternately positive and negative. When τ and $(\varphi-\varphi')/\tau$ have the same signs (the usual case), the lower wire, No. 1, is of greater viscosity. In case of $\theta=100°$, only a part of the upper wire, length $a=\alpha-\beta$, could be heated; the remainder being kept at the lower temperature θ'. Time is conveniently given in minutes, reckoned after twisting.

* In how far such reductions are generally permissible, cf. Weidmann: Wied. Ann., xix, p. 220, 222, 1886.

TABLE 1.—VISCOUS DETORSIONS OF HARD STEEL.

$l=30^{cm}$. $\rho=0{\cdot}0405^{cm}$. $\alpha=28{\cdot}5^{cm}$. $\beta=31{\cdot}5^{cm}$.

No. An.	$\frac{\tau}{2(\phi+\phi')}$	θ θ'	Time.	$\frac{\phi-\phi'}{\tau}\times 10^3$	No. An.	$\frac{\tau}{2(\phi+\phi')}$	θ' θ	Time.	$\frac{\phi-\phi'}{\tau}\times 10^3$
2	—·1045	20	3	+ 0·00	2	—·1027	100	2	— 0·00
450°		20	17	·04	450°		20	6	— 1·35
			50	·07				18	— 2·89
	—·0003		60	·09				29	— 3·66
								45	— 4·53
						—·0020		58	— 5·10
	+·1027	20	1	— 0·00		+·1027	100	2	+ 0·00
		20	8	— ·09			20	20	2·51
			28	— ·18				33	3·76
	+·0020		52	— ·18		+·0020		47	4·72
3	—·1033	20	2	+ 0·00	3	—·1027	100	2	— 0·00
450°		20	6	·25	450°		20	11	— 1·30
			19	·49				20	— 1·78
			28	·63				34	— 2·22
	—·0014		44	·71		—·0020		48	— 2·89
	+·1030		2	— 0·00		+·1027	100	2	+ 0·00
			8	— ·04			20	10	4·58
			20	— ·04				18	6·84
	+·0017		30	— ·04		+.0020		24	8·09
4	—·1033	22	2	— 0·00	4	—·1007	100	3	— 0·00
360°		22	17	— ·27	360°		22	15	— 2·56
			42	— ·35				28	— 3·64
	—·0014		54	— ·35		—·0041		46	— 4·48
	+·1007	22	1	+ 0·00		+·0998	100	2	+ 0·00
		22	33	2·13			22	12	7·83
			44	2·33				22	11·21
	+·0041		64	2·56				37	14·49
						+·0049		49	16·28
5	—·1027	23	2	— 0·00	5	—·1019	100	3	— 0·00
360°		23	15	— ·27	360°		23	22	— 3·30
			21	— ·36		—·0029		32	— 4·32
	—·0020		34	— ·40					
	+·1021	23	2	+ 0·00		+·1015	100	2	+ 0·00
		23	12	·36			23	7	3·12
			19	·42				20	5·94
	+·0026		27	·45		+·0032		27	6·97
6	—·1035	19	2	— 0·00	6	—·1023	100	1	— 0·00
190°		19	5	— ·18	190°		19	4	— 5·42
			17	— ·40				12	—11·79
			35	— ·26				20	—15·28
								29	—19·05
	—·0012					—·0024		36	—19·63
	+·1035	19	2	+ 0·00		+·1003	100	1	+ 0·00
		19	19	·00			19	5	12·02
			31	·09				10	19·53
								15	24·96
								20	28·71
								26	32·56
								32	35·42
	+·0012					+·0044		38	38·02

TABLE 1—*continued.*

7	—·1027	20	2	— 0·00	7	—·1007	100	1	— 0·00
190°		20	8	— 0·93	190°		20	3	— 5·70
	—·0020		18	— 1·48				8	—16·33
								19	—28·63
								33	—36·79
						—·0041		40	—39·64
	+·1009	20	1	+ 0·00		+·1003	100	2	+ 0·00
		20	9	1·69			20	9	15.89
			20	2·56				16	23·58
			30	3·01				26	30·39
	+·0038		50	3·74		+·0044		40	36·40
8	—·1035	20	2	— 0·00	8	—·1007	100	3	— 0·00
190°		20	12	— ·35	190°		19	11	—13·27
			19	— ·54				20	—21·34
	—·0012		27	— ·54				32	—27·45
						—·0041		55	—35·12
	+·1030	20	2	+ 0·00		+·0995	100	2	+ 0·00
		20	9	0·63			19	11	25·08
			17	1·03				22	39·11
			33	1·43				28	43·09
	+·0017		44	1·66		+·0052		41	50·86
9	—·1033	19	2	— 0·00	9	——	100	2	— 0·00
100°		19	8	— 0·79	100°	——	19	5	—25·74
	—·0014		27	— 2·14				8	—39·60
	+·1023	19	3	+ 0·00		Accident.			
		19	10	1·49					
			31	3·37					
	+·0023		42	3·97					
10	—·1041	20	1	— 0·00	10	—·0974	100	1	— 0·00
100°		20	12	— 1·33	100°		20	3	—29·97
			25	— 1·94				7	—47·54
	—·0006		38	— 2·39				16	—82·69
								19	—91·64
						+·0073		21	—96·51
	+·1023	20	2	+ 0·00		+·0968	100	2	+ 0·00
		20	21	2·52			20	5	22·18
	+·0023		45	3·60				8	35·89
								12	48·97
								18	63·17
								22	70·81
								25	76·16
								32	87·40
								35	90·05
						+·0078		42	99·65
11	—·1033	21	1	— 0·00	11	+.1007	100	2	— 0·00
100°		21	8	— 0·67	100°		20	5	—12·59
			32	— 1·16				10	—23·80
	—·0014		48	— 1·29				16	—32·45
								22	—38·95
						—·0041		26	—42·69
	+·1027	21	2	+ 0·00		+·0966	100	3	+ 0·00
		21	12	1·71			20	5	8·51
			26	2·65				16	45·41
			37	3·14				23	59·98
	+·0020		50	3·57				31	73·30
								37	81·72
						+·0081		45	91·75

TABLE 1—*continued.*

$l=30^{cm}$. $\rho=0{\cdot}0405^{cm}$. $\alpha=28{\cdot}5^{cm}$. $\beta=31{\cdot}5^{cm}$.

12 25°	+·1007	22	2	+ 0·00
		22	5	3·30
			11	6·14
			29	10·07
	+·0041		36	11·07
	−·0993	22	2	− 0·00
		22	13	− 7·41
			20	− 9·16
	−·0053		25	−10·26
13 25°	−·1007	20	3	− 0·00
		20	12	− 3·52
			22	− 5·26
	−·0041		36	− 6·87
	+·1001	20	2	+ 0·00
		20	6	2·90
			14	5·66
			26	7·92
			31	8·61
	+·0047		41	9·62
	−·1019	20	4	− 0·00
		20	9	− 1·09
			17	− 2·26
			23	− 2·90
			36	− 3·98
			45	− 4·53
	−·0029		59	− 5·43

14 25°	−·1003	20	2	− 0·00
		20	10	− 5·78
			21	− 8·63
			31	−10·19
	−·0044		42	−11·48
	+·0989	20	2	+ 0·00
		20	7	4·19
			14	6·89
			18	7·96
	+·0057		23	8·95
	−·1021	20	5	− 0·00
		20	15	− 1·99
			37	− 4·11
			57	− 5·18
			63	− 5·60
	−·0026		82	− 6·38
	+·1019		1	+ 0·00
	+·0029		111	11·22
17 100°	+·1041	22	2	+ 0·00
		22	12	1·50
			22	2·21
	+·0006		34	2·74
	−·1033	22	1	− 0·00
		22	15	− 2·41
			28	− 3·21
	−·0014		40	− 3·75
	+·1038	22	2	+ 0·00
		22	9	1·15
			19	1·91
	+·0009		27	2·26

The following table 2 is interpolated from the preceding, and contains mean values of $(\varphi-\varphi')/\tau$, as derived from the two twists, τ, alternately positive and negative. The justification of this mode of obtaining data for a chart is given in § 9. Besides these data table 2 contains the number and temper ("An."), and the electrical constant* (specific resistance, s_0, microhms, *cc*, 0° *C.*), as well as the differences s_0-s_0' and $s_{100}-s_{20}'$, in which the subscripts are the temperatures at which s is taken, and s' is the constant of the normal rod, No. 1. Hence these electrical differences correspond to $(\varphi-\varphi')/\tau$, when $\theta=0°$ *C.* and when $\theta=100°$ *C.*, respectively. For No. 1, $s_0'=18{\cdot}6$, $s_0-s_0'=0{\cdot}$ and $(\varphi-\varphi')/\tau=0$. The values $(\varphi-\varphi')/\tau$ are in the same horizontal row with the temperatures, θ, to which they belong. It is not necessary to distinguish $s_0-s'_0$ and $s_{20}-s'_{20}$, here.

* For definition of thermo-electric hardness, cf. Bull. No. 14, p. 65.

TABLE 2.

Values of $\frac{\phi-\phi'}{\tau}\times 10^3$, at different consecutive times.

	No. s_0	$s_0-s'_0$. $s_{100}-s'_{20}$	θ	Time= 2m.	5m.	10m.	20m.	30m.	40m.	50m.
An. 450°.	2	0·8	20	−0·00	− ·04	− ·07	− ·10	− ·12	− ·14	− ·15
	19·4	5·9	100	+0·00	+ ·82	+1·65	+2·76	+3·63	+4·26	+4·84
	3	0·6	20	−0·00	− ·09	− ·18	− ·28	− ·34	− ·38	− ·40
	19·2	5·6	100	+0·00	+1·69	+2·90	+4·48	+5·75	+ ---	----
An. 360°.	4	0·4	22	+0·00	+ ·21	+ ·50	+ ·82	+1·00	+1·09	+1·17
	19·0	5·5	100	0·00	2·32	4·70	7·05	8·70	9·80	10·80
	5	1·5	23	0·00	·11	·25	·37	·43	----	----
	20·1	6·5	100	0·00	1·65	2·90	4·60	5·88	----	----
An. 190°.	6	10·2	19	0·00	·09	·18	·23	·23	----	----
	28·8	15·8	100	0·00	4·40	11·00	18·70	23·30	26·40	----
	7	12·3	20	0·00	·67	1·27	1·90	----	----	----
	30·9	17·7	100	0·00	7·50	16·30	26·50	32·20	36·50	----
	8	12·7	20	0·00	·21	·49	·83	·98	----	----
	31·3	17·8	100	0·00	9·00	19·00	30·20	36·70	41·30	----
An. 100°.	9	18·6	19	0·00	·44	·98	1·74	2·26	----	----
	37·2	24·2	100	0·00	25·70	48·50	----	----	----	----
	10	15·6	20	0·00	·63	1·25	2·00	2·48	2·84	----
	34·2	21·0	100	0·00	20·50	41·00	69·50	----	----	----
	11	14·9	21	0·00	·47	1·00	1·57	1·90	2·14	2·33
	33·5	20·5	100	0·00	13·00	28·50	48·00	61·50	----	----
	12	20·8	20	0·00	3·50	6·15	8·83	10·75	----	----
	39·2	----	----	----	----	----	----	----	----	----
	13	18·4	20	0·00	1·67	3·29	5·15	6·35	----	----
	37·0	----	----	----	----	----	----	----	----	----
	14	22·1	20	0·00	3·10	5·80	8·50	10·15	11·46	----
	40·6	----	----	----	----	----	----	----	----	----

7. Before proceeding to a discussion of the results in tables 1 and 2, I will insert a few introductory data which hold for pure platinum. The plan of tabulation and comparison is the same as that explained for steel, in the remarks preceding table 1. τ, here is small, and $2(\varphi+\varphi')$ large relatively to these data, because soft platinum is much more liable to assume permanent set than steel. Moreover τ is impressed negatively throughout; the changes of sign of $(\varphi-\varphi')/\tau$ are explained in the text below the table, and it is to this text that the letters *a*, *b*, ... *f*, refer.

TABLE 3.

Viscous detorsion of platinum $\theta=\theta'$.

	$\frac{\tau}{2(\phi+\phi')}$	Remarks.	Time.	$\frac{\phi-\phi'}{\tau}\times 10^3$		$\frac{\tau}{2(\phi+\phi')}$	Remarks.	Time.	$\frac{\phi-\phi'}{\tau}\times 10^3$
$l=26{\cdot}2^{cm}$	$-{\cdot}0867$	*a*	2	$-0{\cdot}00$		$-{\cdot}0436$	*d*	2	$-\ 0{\cdot}00$
$\rho={\cdot}0215^{cm}$			9	$-3{\cdot}31$				7	$-22{\cdot}20$
			15	$-4{\cdot}42$				17	$-41{\cdot}40$
			27	$-5{\cdot}65$				25	$-50{\cdot}20$
	$-{\cdot}0344$		33	$-5{\cdot}89$				43	$-61{\cdot}40$
	$-{\cdot}0652$	*b*	2	$-0{\cdot}00$		$-{\cdot}0773$		54	$-65{\cdot}80$
			17	$-3{\cdot}59$		$-{\cdot}0383$	*e*	3	$+\ 0{\cdot}00$
	$-{\cdot}0556$		44	$-4{\cdot}90$				7	$5{\cdot}56$
	$-{\cdot}0443$	*c*	1	$+0{\cdot}00$				26	$19{\cdot}60$
			4	$20{\cdot}60$				47	$27{\cdot}80$
			14	$46{\cdot}80$		$-{\cdot}0826$		55	$30{\cdot}00$
			28	$61{\cdot}90$	$l=26{\cdot}5^{cm}$	$-{\cdot}0396$	*f*	3	$-\ 0{\cdot}00$
	$-{\cdot}0766$		44	$71{\cdot}90$	$\rho={\cdot}0212^{cm}$			8	$-10{\cdot}90$
								13	$-17{\cdot}50$
								29	$-29{\cdot}20$
								37	$-33{\cdot}00$
						$-{\cdot}0813$		46	$-36{\cdot}80$

The two wires of table 3 were originally identical, so that the apparatus showed $\varphi=\varphi'$. Both wires were then twisted, but the lower more than the upper. The results under *a* indicate greater viscosity for the lower, a state of things which is only partially wiped out by annealing at red heat, in air, as indicated under *b*. I then commenced the experiments proper of the table, by leaving the upper wire untouched and annealing the lower wire at red heat. The results under *c* indicate an enormous difference, the un-annealed wire being of greater viscosity. I then left the lower wire untouched and annealed the upper wire at red heat. The results under *d* again show an enormous difference, the un-annealed wire (now the lower) being of greater viscosity. I then again annealed the lower wire only, obtaining the results under *e*, corresponding to *c*, and finally again annealed the upper wire only, obtaining the results under *f*, corresponding to *d*. The operation of alternate annealing might have been continued very much longer with practically the same results. In each case the freshly annealed wire shows a pronounced loss of viscosity, as compared with an otherwise identical wire, slightly twisted beyond the elastic limits.

As compared with the effects of alloying, I found this result so large as to compel me to abandon my experiments on the viscosity of series of platinum alloys,—at least until the mechanical error in question has been interpreted and brought under control.

When two wires as nearly as possible identical (chemically and physically) are compared, the question arises in how far viscosity may vary with the time elapsed after annealing. The experiments made showed slight increase with the time given to the molecules to subside after annealing in air. The magnitude of these results is insignificant and often obscure and by no means comparable with the data of table 3. It follows that these are not a direct heat effect. Again the sign of the twist τ, in table 3, is the same throughout. It must therefore be asked whether in these experiments an earlier stage of viscous subsidence overtakes a later stage. To throw light upon this point, it is sufficient to reverse the sign of the twist alternately, without fresh annealing; or to reverse the sign of the twist with each alternate annealing of the upper and lower platinum wire. In such a case a latent strain, favorable to motion, is imparted to the wire not annealed. Experiments which I made in some number show that the results of table 3 hold good, the character of the motion being diminished in degree, but not in sign.

All these results follow at once from Maxwell's theory. They show that the above viscous effect of twisting is to be referred to motion of molecules which accompanies it; molecules are placed in new relations relative to each other; unstable configurations are thus continually broken up, the action beginning at the outside layers. By reversing the sign of the twist, the original configurations are only partially restored, at best, even for small permanent set, such as is here in question. Finally the effect of prolonged and repeated twisting is stiffness, because all the unstable configurations have collapsed, and the intrinsic molecular energy is the potential minimum compatible with the given conditions.

8*a*. Steel wires were used in our earlier work,† free from torsion strain. The hard steel wires of the present paper, employed in other researches, may contain twists stored up like residual magnetism. This produces a kind of unilateral symmetry, so far as torsions are concerned; but it is not otherwise objectionable. In critical cases wires free from latent torsion are selected.

Turning to table 1, the individual wires are found to show wide differences of viscous behavior: In No. 2, the viscous subsidence takes place at nearly the same rate for $-\tau$ and for $+\tau$, both at $\theta=20°$ and at $\theta=100°$. In No. 3 the effect of $-\tau$ and $+\tau$ is of different magnitude at 20°, and enormously more

* The thermal effect without annealing is so nearly negligible as to prove that in Dr. Schroeder's work (Wied. Ann., xxviii, p. 369, §§ 8, 13, 17. 1886), the observed result is to be ascribed to annealing hard drawn wire.

† B. and S.: this Journal, III, xxxii, p. 448, 1886; xxxiv, p. 4, 1887.

different at 100°. In No. 4, the effect of $+\tau$ following $-\tau$ is even more phenomenally pronounced, both at 20° and particularly at 100°. In No. 5 the wires nearly identical at 20° show differences at 100°. In No. 6 this is true in even much greater degree, whereas in No. 7 wires differing considerably at 20°, show relatively small differences at 100°. And so I might go through the series. Nos. 13 and 14 are wires originally free from strain (shear); but vagueness also appears in these.

Careful inspection of the tables reveals the law, that viscous deformation takes place at numerically greater rates during the even twists than during the odd twists which immediately precede them respectively. Aside from these oscillations, the effect of twisting here, as in § 7, is pronounced increase of viscosity.

Maxwell's theory accounts for the stated vagueness of behavior at once. In two samples of a complex substance like steel, the distributions and relations of the unstable molecular configurations will only in very rare instances be physically and chemically identical. The foregoing paragraph shows that such identity is rare even in pure homogeneous metal. § 9.

The effect of twisting alternately in opposite directions is of so great importance in its bearing on Maxwell's theory that I made further special experiments. From these I select the following example, tabulating it as in case of table 1. The normal No. 1, An. 450° has been described. No. 18, An. 25°, or glass-hard, is carefully selected free from latent torsion, having experienced no other strain prior to the examination in table 4, than that incident to tempering (quenching). There are twelve alternations of twist, indicated by subscripts, and the current time in hours and minutes of each is given. I also give under m, the time in minutes which refers specially to the duration of each twist. No. 1 being of greater viscosity, τ and $(\varphi-\varphi')/\tau$ are alike in sign, by agreement.

Experiments made by counter-twisting two glass-hard wires gave results like this, but on a smaller scale. To compare the results of table 4 perspicuously it is sufficient to construct the differences, $\Delta\,(\varphi-\varphi')/\tau$, of the respective value of $(\varphi-\varphi')/\tau$, at *two* and *four* minutes after twist is imparted. These are then to be compared in their dependence on current time. Phenomena of this kind were called "accommodation" by Streintz,* their discoverer, by Wiedemann,† Kohlrausch,‡ and others. The fact that Boltzmann's law contains them is among its chief excellencies.

* Streintz: Pogg. Ann., cliii, p. 406, 1874.

† Wiedemann: Wied. Ann., vi, p. 512, 1879. This work is the most searching and comprehensive of the relevant researches.

‡ Kohlrausch: Pogg. Ann., clviii, p. 371, 1876. Cf. Schmidt: Wied. Ann., ii, p. 48, 1877.

TABLE 4.

Viscous effects of twisting glass-hard steel alternately in opposite directions. Normal wire No. 1; $l=30^{cm}$ $\rho=\cdot0405^{cm}$.

Remarks.	τ	Time.	m	$\frac{\phi-\phi'}{\tau}\times10^3$
No. 18_1	$-\cdot102$	$9^h\ 13^m$	0	----
An. 25°		15	2	$-0\cdot00$
		17	4	$-1\cdot90$
		28	15	$-5\cdot90$
		35	22	$-7\cdot30$
No. 18_2	$+\cdot102$	$9^h\ 37^m$	0	----
		39	2	$+0\cdot00$
		41	4	$2\cdot30$
		52	15	$7\cdot50$
		60	23	$9\cdot35$
No. 18_3	$-\cdot102$	$10^h\ 2^m$	0	----
		4	2	$-0\cdot00$
		8	6	$-2\cdot10$
		19	17	$-4\cdot75$
		25	23	$-5\cdot70$
No. 18_4	$+\cdot102$	$10^h\ 28^m$	0	----
		30	2	$+0\cdot00$
		36	8	$2\cdot95$
		41	13	$4\cdot40$
		48	20	$5\cdot60$
No. 18_5	$-\cdot102$	$10^h\ 50^m$	0	----
		52	2	$-0\cdot00$
		59	7	$-2\cdot30$
		70	20	$-3\cdot95$
No. 18_6	$+\cdot102$	$11^h\ 11^m$	0	----
		13	2	$+0\cdot00$
		15	4	$1\cdot10$
		25	14	$3\cdot75$
		33	22	$4\cdot95$
No. 18_7	$-\cdot102$	$11^h\ 35^m$	0	----
		37	2	$-0\cdot00$
		39	4	$-0\cdot75$
		56	21	$-3\cdot45$
		57	22	$-3\cdot55$

Remarks.	τ	Time.	m	$\frac{\phi-\phi'}{\tau}\times10^6$
No. 18_8	$+\cdot102$	$12^h\ 0^m$	0	----
		2	2	$+0\cdot00$
		4	4	$0\cdot85$
		20	20	$3\cdot80$
No. 18_9	$-\cdot102$	$12^h\ 24^m$	0	----
		26	2	$-0\cdot00$
		28	4	$-0\cdot60$
		40	16	$-3\cdot45$
No. 18_{10}	$+\cdot102$	$12^h\ 42^m$	0	----
		44	2	$+0\cdot00$
		46	4	$0\cdot80$
		54	12	$2\cdot55$
		63	21	$3\cdot70$
No. 18_{11}	$-\cdot102$	$1^h\ 5^m$	0	----
		7	2	$-0\cdot00$
		9	4	$-0\cdot65$
		21	16	$-2\cdot55$
No. 18_{12}	$+\cdot102$	$1^h\ 23^m$	0	----
		25	2	$+0\cdot00$
		27	4	$0\cdot70$
		36	13	$2\cdot45$
After several days.				
No. 18_{13}	$-\cdot102$	$9^h\ 47^m$	0	----
		49	2	$-0\cdot00$
		51	4	$-0\cdot90$
		60	13	$-3\cdot00$
No. 18_{14}	$+\cdot102$	$10^h\ 2^m$	0	----
		4	2	$+0\cdot00$
		6	4	$1\cdot00$
		15	13	$6\cdot40$
No. 18_{15}	$-\cdot102$	$10^h\ 17^m$	0	----
		19	2	$-0\cdot00$
		21	4	$-0\cdot90$
		30	13	$-3\cdot20$

TABLE 5.—*Viscous accommodation of glass-hard steel.*

Twist No.	Time.	$\Delta\frac{\phi-\phi'}{\tau}\times10^3$	Twist No.	Time.	$\Delta\frac{\phi-\phi'}{\tau}\times10^3$	Twist No.	Time.	$\Delta\frac{\phi-\phi'}{\tau}\times10^3$
1	0^m	$-1\cdot90$	5	97^m	$-1\cdot00$	9	191^m	$-\ \cdot60$
2	24	$+2\cdot30$	6	118	$+1\cdot10$	10	209	$+\ \cdot80$
3	49	$-1\cdot20$	7	142	$-0\cdot75$	11	232	$-\ \cdot65$
4	75	$+1\cdot40$	8	167	$+0\cdot85$	12	250	$+\ \cdot70$

If the numerics of $\Delta(\varphi - \varphi')/\tau$ be regarded in their dependence on time, the results are seen to oscillate around a mean line of equilibrium. The ordinates of this mean line decrease with time at a gradually retarded rate, until a definite inferior limit is eventually reached. It is curious to note that the largest observed ordinate (time $= 0$, nearly), is at least 3 times the limiting ordinate (time $= \infty$). After 12 twists oscillation has considerably subsided, but it has not ceased; in the same degree the viscosity of the glass-hard rod has reached a fixed maximum.

This complicated phenomenon is at once elucidated by Maxwell's theory. The ordinates of the line around which oscillation takes place, are an index of the degree of instability of molecular configuration, at the time given by the abscissæ. The oscillations are the result of strain (latent shear, I called it) imparted to the configurations by the successive twists to which the wire is subjected. Thus if τ be the impressed twist, and $\Delta\tau$ the mean strain left in the configurations at the instant when τ is removed; and if n be the original relative number of unstable configurations, and Δn the number broken up during the period of the strain τ; then (apart from subsidiary considerations) Maxwell's theory analyzes the effects of alternate twisting in accordance with the following scheme:

	Strain.	Molecular instability.
First twist	$-\tau$	$+n$
Second twist	$+\tau+\Delta\tau$	$+n-\Delta n$
Third twist	$-\tau+\Delta_1\tau-\Delta'\tau$	$+n-\Delta_1 n-\Delta' n$
Fourth twist	$+\tau+\Delta_2\tau-\Delta'_1\tau+\Delta''\tau$	$+n-\Delta_2 n-\Delta'_1 n-\Delta'' n$
Fifth twist	$-\tau+\Delta_3\tau-\Delta'_2\tau+\Delta''_1\tau-\Delta'''\tau$	$+n-\Delta_3 n-\Delta'_2 n-\Delta''_1 n-\Delta''' n$

The variation which Δ undergoes in passing from one twist to the next is indicated by subscripts. Thus $\Delta\tau$, $\Delta_1\tau$, $\Delta_2\tau$, ... is probably a decreasing series; whereas Δn, $\Delta_1 n$, $\Delta_2 n$, ... is an increasing series because reversal of the sign of the twist must be supposed to reconstruct some of the configurations broken up by the preceding twist. The first part of the scheme indicates that the strain in the 2d, 4th, 6th ... twists is necessarily greater than the strain in the immediately preceding 1st, 3d, 5th ... twists respectively, at least at the outset of the experiments. Hence the observed oscillation. Again the number of unstable configurations must continually decrease, according to the second half of the scheme. Hence the mean line about which the observed viscous deformations oscillate. Finally experiment shows that the accelerating effect of $\Delta\tau$ on viscous deformation is greater than the retarding effect of $-\Delta n$. After this, however, the accelerating effect of $\Delta_2\tau - \Delta'_1\tau + \Delta''\tau$, and the succeeding τ-quantities, is always less than the retarding

effect of $-\Delta_2 n - \Delta_1 n - \Delta'' n$, and the succeeding n-quantities, respectively.

The scheme admits of simplification; but inasmuch as the period of oscillation is arbitrary, the phenomenon remains indefinitely complex.

8*b*. The second part of table 4 shows that the viscosity gained in virtue of consecutive alternate twisting of glass-hard steel is permanently gained. The results indicate some recuperation; but the amount is small in comparison with the havoc of configurations made by twisting. Mere molecular motion has therefore permanently broken the more unstable configurations. I will note that the viscous effect of prolonged twisting to and fro in case of glass-hard steel, is of the same order of magnitude as the effect of prolonged annealing at 100°. This indicates the importance of the motional effect in question.

If, following the analogy of steel, I consider annealing a process by which unstable configurations are broken up, I may with due caution designate the phenomenon here in question as motional annealing. Experiments for which there is no room here showed that motional annealing is relatively without electrical effect. For increasing rates of twist thick wires show viscous deformation sooner than thin wires. Hence motional break up commences at the external surface where stress is most intense, and proceeds thence toward the axis where stress is least Thus there appears an essential dependence on the dimensions of the twisted rod. Elsewhere * I pointed out that the limits of torsional resilience of soft iron are reached when the obliquity of the external fiber (shear) somewhat exceeds ·003 radians. Regarding the laws of motional annealing, cf. § 16. It follows from the absence of electrical effect, that motional annealing probably presents a pure case of Maxwell's "break up" of configurations of molecules.

8*c*. Streintz and Wiedemann's phenomenon "accommodation" admits of representation from a different point of view. Returning to the data of table 4, suppose the experiment so conducted that the twelve twists are immediately consecutive. Suppose furthermore that time, m, instead of being reckoned positively onward from the beginning of each of the said twists, were reckoned alternately positive and negative, conformably with the sign of the deformations $(\varphi-\varphi')/\tau$. In this oscillatory march (time as abscissa), since each deformation (ordinate) now begins where the preceding deformation ceased, a continuous series of open cycles is necessarily generated. The positions of these cycles shift at a gradually retarded rate, toward a final very flat cycle, which for the constant values of time and stress is fixed in position and closed.

* This Journal (III), xxxiv, p. 183, 1887.

Cycles here, fixed or not, are expressions of the fact that the "past histories" (in Maxwell's words) of the molecular configurations in the "stress positive" and "stress negative" phase of each cycle are not the same. Shifting is brought about by permanent molecular break up, the amount of which gradually vanishes. In the ultimate and fixed cycle as many configurations are broken during the "stress positive" as are reconstructed in the "stress negative" phase, though they need not be the same configurations.

These considerations suggest a comparison between "accommodation" and Prof. Ewing's* "hysteresis," for the purpose of detecting the extent to which like causes are discernable in each phenomenon. Both exhibit a static character. But such comparison would not be fruitful without special and direct experiments; for the *instantaneous* values of stress and of viscosity must be coördinated.

9. Having thus discussed one phase of the results in table 1, I pass to table 2, which is a digest of the mean values of table 1, in so far as such a digest can be made. Following the scheme at the end of the preceding paragraph, this comparison should be made after an infinite number of twists have been imparted to each wire. In such a case, however, the original number of unstable configurations has been seriously reduced; so that apart from the annoyance of so time-consuming a method as this, the original properties of the wire are not clearly present in the results. In wires perfectly free from strain, at the outset, the first twist leads to the best indications of the viscous quality. As this condition could not always be guaranteed for the wires of this paper, I have accepted the mean viscous behavior during the first and second twists as the best available index for comparison. It is sufficient, at least for the present purposes. Again taking the mean for rods of the same nominal temper, I obtain data from which a chart is easily constructed, by representing mean viscous deformation $(\varphi-\varphi')/\tau$, varying with time, for each of the divers degrees of hardness An. 25°, An. 100°, An. 190°, An. 360°, An. 450°. It so happens that the normal rod, No. 1, is less viscous than the other rods, No. 2 and No. 3, of like temper. Hence the negative numbers in table 2, which may be eliminated by increasing the other data.

Returning to table 2, it is clear, inasmuch as viscous deformations are measured differentially, that $(\varphi-\varphi')/\tau$ and $\Delta_0-\Delta'_0$ are to be compared It appears that these quantities increase and decrease together. This is more easily discernable when

* Ewing: Phil. Trans. Roy. Soc., II, p. 523, 1885; ibid., II, p. 361, 1886. Prof. Ewing's earlier papers are there given. Cf. also Cohn, Wied. Ann., vi, p. 403, 1879.

rods free from strain are compared.* The exceptions of table 2 are due to the fact that latent strains influence $(\varphi-\varphi')/\tau$ to a relatively much greater extent than $\Delta_0-\Delta'_0$. Again if $\Delta_{100}-\Delta'_{20}$ and $(\varphi-\varphi')/\tau$ be compared at 100°, table 2 shows that in this case also the two quantities increase and decrease together. Indeed the data for 100° are the more uniform, a result due to the fact that at 100° much of the latent torsion is made to vanish because of the annealing effect of 100°. Data of even greater uniformity *cæt. par.* are to be looked for at higher temperatures.†

If a comparison is made between the mean rates at which viscous deformation and resistance increase together with temper, at 20° ($(\varphi-\varphi')/\tau$ and $\Delta_0-\Delta'_0$), and at 100° ($(\varphi-\varphi')/\tau$ and $\Delta_{100}-\Delta'_{20}$), it is seen that the mean rate of increase of $(\varphi-\varphi')/\tau$ relatively to $\Delta-\Delta'$ is about ten times as great at 100° as at 20°. This is the phenomenon in virtue of which the viscous behavior of steel, regarded as a test of Maxwell's theory, is almost crucially important. I shall endeavor to explain it.

10. Dr. Strouhal and I defined the glass-hard state of steel‡ as the stage of temper which undergoes incipient annealing at mean atmospheric temperature. Inasmuch therefore as annealing is demonstrably accompanied by chemical decomposition§ even at temperatures slightly above mean atmospheric, the molecular configuration of glass-hard steel is always in a state of incipient change ‖ A part, though not the whole, of this change must be of a permanent kind; and I wish to keep in mind that at the temperature of incipient annealing the heat motion is such that broken configurations are sometimes reconstructed.

Inasmuch therefore as glass-hard steel contains more unstable configurations than any other state of temper, at the same temperature, it follows from Maxwell's theory that glass-hard steel, despite extreme hardness, must be the least viscous member of the whole group of tempered and soft steel. This strikingly anomalous prediction of the theory is verified both by the re-

* B. and S.: this Journal, (III), xxxiii, pp. 26, 27, 1887.

† Maxwell's words are (l. c): ". . . but if, on account of rise of temperature . . . the breaking up of the less stable groups is facilitated, the more stable groups may again assert their sway, and tend to restore the body to the shape it had before deformation."

‡ Wied. Ann., xi, pp. 962, 963, 1880.

§ B. and S.: This Journal, (III), p. 276, 1886.

‖ During the last three years I have been making experiments on the secular annealing of cold hard steel. The results are very striking and show that mean atmospheric temperature acting on freshly quenched steel for a period of years, produces a diminution of hardness nearly equal to that of 100° C., acting for a period of hours. I examined some twenty rods, the specific resistance of which, within thirty-seven months, has fallen from 46·5 to 42·5, in the case of thin rods (diameter $<0{\cdot}08^{cm}$), and from 43·7 to 35·4 in the case of thicker rods (diameter $0{\cdot}13^{cm}$). Freshly quenched pieces showed resistances as high as 50, nearly.

sults of table 2, as well as in earlier work* in a way so pronounced as to be irrefragable.

If glass-hard steel is annealed at 100°, the greater number of the unstable configurations are broken up in virtue of the increased molecular vibration at the higher temperature. The cold rod, after annealing, will show increased viscosity in proportion as the number of unstable configurations has decreased. Experiment proves this in a strikingly conclusive way: the increase of viscosity thus produced is marked, being nearly half the difference between the soft and hard states of steel. This, too, is an observation favorable to Maxwell's theory; for if there be configurations with an inherent tendency to collapse at ordinary temperatures, but a small fraction of them will survive at 100°. Moreover the configurations broken up cannot be reconstructed without expenditure of fresh energy (quenching). Since no such energy is ordinarily available, the viscous properties of the annealed rod are of a permanent kind.

Again if glass-hard steel (or steel annealed at 100°) be softened by annealing at 200°, a greater number of unstable groups will be broken up than in the foregoing case. The viscosity of the cold rod must therefore be considerably greater than that of the hard rod. Experiment proves the viscous increase to be about two-thirds of the whole viscous difference between hard and soft steel. Analysis gives evidence of the occurrence of decomposition; and inasmuch as the unstable groups are permanently broken, the annealed rod shows determinate viscous properties.

If glass-hard steel be annealed at 300°, 400°, 500°, etc., effects of the same nature as those just discussed, but differing from them in the degree of thorough removal of the unstable configurations, will result.

The phenomenon as a whole must be considered continuous, both as regards temperature and time. In proportion as temperature is higher, however, Maxwell's theory predicts that the effects of the same increment of the temperature of annealing, will produce increments of viscosity successively diminishing at a very rapid rate. Supposing molecular configurations originally present in all states of stability, it follows at once that the groups which retain this quality after annealing must very soon vanish when the temperature of annealing is increased. The data prove this in a convincing way: Rods annealed at 300°, 400°, 500°, ... 1000°, show about the same viscous behavior (relatively speaking), notwithstanding the fact that chemical analysis proves that the decomposition incident to the successive application of these temperatures on glass-

* B. and S.: This Journal, xxxiii, pp. 25, 26, 1887.

hard steel, continues steadily to increase.* Indeed chemical decomposition above 300° is more marked than below 300°; yet its bearing on Maxwell's theory is now without interest, because in none of the high annealed rods do configurations unstable at mean atmospheric temperature survive after annealing.

11. Having analyzed the phenomena at mean atmospheric temperature, I come next to consider the conditions of mean relative viscosity at 100°. The glass-hard state must here be withdrawn, for consideration in § 13; because such a rod would undergo annealing during the viscous measurements at 100°.

Hard steel annealed at 100° bears the same relations to 100° that glass-hard steel does to mean atmospheric temperature. Hence the reasoning of the preceding paragraph, *mut. mut.*, applies at once. It is merely necessary to bear in mind, that 100° is now the temperature of incipient annealing, and that therefore the temperatures which produce corresponding viscous effects are proportionately higher. Rods An. 200° now occupy about the same relative position that rods An. 100° did in § 9; An. 300° the same relative position as An. 200°, etc. Moreover for equal increments of the temperature of annealing, the increment of viscosity shown by the rod at 100° diminishes rapidly as temperature increases, etc.

In one respect the present results differ from the above: the phenomena are here spread out over a scale (roughly estimated) about ten times larger. This means, following Maxwell's theory, that at 100° the number of unstable molecular configurations is relatively much larger than at mean atmospheric temperature. The reasons, though not far to seek, are exceedingly significant. In hard steel, at 100° two causes of molecular instability here produce superposed effects. The first is the chemical or carbon instability already discussed; the second cause is purely thermal. Cf. § 17.

The explanation of the diagram for 100° is now clear. Viscous deformation is marked in all the rods examined for An. 500° to An. 100°; but the deformability increases at a rapid pace in proportion as we pass from softer to harder steel, because in such a march the carburation instability, superimposed upon the thermal instability, increases rapidly. Molecular configurations on the verge of instability are encountered in continually increasing numbers.

12. The line of argument followed out for 100°, applies *mut. mut.* at 200°. Results of this kind I published elsewhere.† The character of the evidence bearing on all the points in question is here even more pronounced and conclu-

* This Journal, xxxii, pp. 277, 282, 1886.
† This Journ., III, xxxiv, p. 14 to 16, 1887.

sive. Steel An. 200° is in a state of incipient annealing at 200°. Thermal and carburation instabilities of high degree being superposed, the effects are correspondingly large.

Finally above 300° the molecular instability is largely thermal. The behavior of hard steel therefore approaches that of other metals more nearly.* The effect of the carburation instability ceases to predominate, and finally vanishes altogether in proportion as the march is made from lower to higher temperatures of annealing.

13. I have finally to touch upon the series of phenomena in which pronounced annealing occurs simultaneously with pronounced external viscous deformation. If, for instance, a glass-hard rod is twisted and then suddenly heated to 100°, the rod is both annealed and suffers deformation in virtue of the applied twist at the given temperature. Conformably with the excessively greater amount of molecular instability which characterizes these experiments, the observed viscous deformation must be proportionately large. This prediction of Maxwell's theory is fully verified by experiment. In the case of the twisted rod postulated, the motion of the image across the field of the telescope is so rapid, that Gauss's method of angular measurement is no longer satisfactorily available. I may say without exaggeration, that during the small interval of time within which appreciable annealing occurs, a glass-hard steel rod suddenly heated to 300°, is a viscous fluid. I have shown† that if a glass-hard and a soft rod (*cœt. par.*) be identically twisted and heated to 350°, the former will have lost all its strain, whereas in the soft rod only about $\frac{1}{3}$ will have vanished.

Advantage may be taken of two simultaneous causes of molecular instability in other and purely mechanical ways. Thus molecular instability is produced by drawing soft steel wire through a draw-plate, and the instability increases enormously with the intensity of the strain. Experiments which I made in some number by counter-twisting soft and hard drawn steel wire at 30° and at 100°, showed results quite comparable in striking interest with the behavior of tempered steel. The character of both phenomena is the same, so that as far as viscous comparisons go, the drawn strain replaces the temper strain perfectly. Cf. § 17.

14. Viscosity in the above pages has been considered apart from the stress-intensity under which the deformation takes place. This is liable to lead to confusion, unless the stress relative to which the constants of viscosity are defined, be kept clearly in mind; or unless the terms viscosity be applied

* Cf. § 17.

† This Journal, III, xxxiv, p. 4, 5, 1887. Experiments made by annealing twisted systems.

to solids in the restricted sense of "elastische Nachwirkung." Thus if a glass-hard and a soft steel rod be subjected alike and at ordinarry temperature to torsional stress of continually increasing magnitude, a stress value will be reached for which the viscosity of the hard rod will be equal to, and eventually overtake the viscosity of the soft rod. I was able to exhibit this phenomenon in even a more striking way at 190°, finding that for rates of twist less than $\tau=3°$, steel rod (radius$=0·041^{cm}$) is much less viscous and more susceptible to the influence of temperature in proportion as it is permanently harder;* whereas for rates of twist greater than $\tau=6°$, steel *cæt. par.* is less viscous and more susceptible to the influence of the influence of temperature in proportion as it is softer.

Here I may profitably advert to certain considerations postulated in an earlier paper† relative to the association of hardness with resistance against ∞-forces acting through zero-time, and the association of viscosity with resistance against zero-forces acting through ∞-time, all magnitudes being regarded from a relative point of view. "We may reasonably conceive," is there further stated, "that in case of viscous motion the molecules slide into each other or even partially through each other, per interchange of atoms, so that the molecular configuration is being continually reconstructed; whereas in the other case (hardness) the molecules are urged over and across each other . . . ." In the ordinary case of scratching the action is usually accompanied by physical discontinuity of the parts tangentially strained.

The intensity of stress by which the above deformations are evoked was nearly constant and equal to 0·5 kg. on centimeter of arm. This couple, when applied to the given steel rods (radius $0·041^{cm}$), is admirably adapted for the exhibition of the nearly *pure* viscous phenomenon, the "Nachwirkung" of Weber and Kohlrausch.

It is just here that certain cardinal distinctions must be made. According to Maxwell's views, viscosity is the same phenomenon in liquids and in solids, and the molecular mechanism by which it manifests itself quite the same in both cases. There is nothing in the theory to induce the reader to limit viscosity in solids to certain special changes of configuration. In solids at high temperatures, and of course in viscous fluids, there is indeed no need of distinction; and viscosity appears as the one property into which the other configuration-properties of solid matter eventually merge. In solids, at low temperatures on the other hand, the case is much more complex; and whereas viscosity ("Nachwirkung") still appears as

* An. 190°, being of course the maximum hardness admissible.

† This Journal, III, xxxiii, p. 28, 1887.

a property common to solids, whether soft or hard, plastic or brittle, these ulterior distinctions softness, hardness, plasticity (permanent set), brittleness, etc., separate solids by very broad lines. Hence it is improbable that the whole mechanism in virtue of which viscous deformations are possible in viscous fluids, is fully of the same nature as that by which viscous motion takes place in solids at ordinary temperatures. Viscosity in liquids is the mean result of divers superposed phenomena, the occurrence of any one of which, in a solid, would give rise to some special physical property of that solid. From this point of view, since viscosity is independent of the other physical properties above enumerated, and since viscosity (Nachwirkung), is common to solids without exception, I have ventured to refer it to such action between contiguous molecules as involves the least amount of free motion. Viscosity in solids, is the result of changes of configuration, resulting from localized thermal agitation, and often superinduced by the atomic attraction of contiguous configurations, in the manner explained by the Clausius-Maxwell principle.*

This premised, further distinctions may be made. Questions arise as to whether such action can be indefinitely repeated without rupture, as in plastic solids, or in viscous fluids; or whether it can not be indefinitely repeated as in brittle solids, etc. The indefinite repetition of the phenomenon is equivalent to a passage of molecules over or across each other, the phraseology above used in reference to hardness.† §18.

The ideas underlying this paragraph may be summarized thus: In passing from the fluid to the solid state of matter, the residual or extramolecular affinities acquire an increased importance relatively to the intermolecular affinities. At the same time the conditions of action have gradually become exceedingly unfavorable. In a liquid, under impressed favorable conditions chemical reaction between molecules is demonstrable (electrolysis). In a solid, under impressed favorable conditions (strain of dilatation) it is also demonstrable, for instance,

* "Betrachten wir ferner das Verhalten der Gesammtmolecüle unter einander, so glaube ich dass es auch hier zuweilen geschieht, dass das positive Theilmolecül eines Gesammtmolecüls zu dem negativen eines anderen in eine günstigere Lage kommt, als jedes dieser beiden Theilmolecüle in Augenblicke gerade zu dem anderen Theilmolecül seines eigenen Gesammtmolecüls hat, etc." Mech. Wärmeth., ii, 2 Aufl, p. 163, 1879. "Again, following Maxwell: ". . . . Thus we may suppose that in a certain number of groups the ordinary agitation of the molecules is liable to accumulate so much that every now and then the configuration of one of the groups breaks up, and this whether it is in a state of strain or not. . . . ."

"But if a solid also contains . . . . groups of the first kind which break up of themselves . . . ." Maxwell, l. c.

† Cf. this Journal, xxxiv, pp. 1, 18, 1887.

in the marked secular annealing of glass-hard steel. It is not necessary for the manifestation of viscosity that the integrity of the molecule be actually invaded; but as the action intensifies one may pass continuously from Maxwell's (§ 8*b*) into Clausius's (§ 15) hypothesis, without being able to define the line of transition, at least from the character of the viscous phenomena. Cf. this Journal, xxxiv, p. 1, 1887.

15. The observations made in the above paragraphs relative to the visible viscous subsidence of a mechanical strain imposed on a steel rod, apply for the complete explanation of the phenomenon of temper. With this purpose in view, it is merely necessary to conceive of hardening or quenching (sudden cooling of steel) as an operation by which a strain of dilatation is imparted to steel. This strain, once applied, is locked up in the metal in virtue of viscosity.* The strained structure of hard steel is proved by the fact that massive pieces of hard steel often explode spontaneously† and by the tendency to rupture during quenching exhibited by the metal. The temper strain may be studied optically and in other ways, in glass, and at low temperatures, even in resin.‡

Reckoned from the observed volume increase§ due to quenching, the stress-intensity corresponding to the observed strain may be estimated at 10^{10} degrees per square cm. in steel, and 10^9 degrees per square cm. in glass. It is thus of the order of the respective tenacities of steel and of glass.

In view of the fact that the viscosity of glass-hard steel is not above that of glass,‖ exceptionally great strain intensity though impartable, would not be permanently retained. Hence the secular changes of glass-hard steel. Cf. § 10, footnote. At this point the function of carbon appears. Sudden cooling induces carbon and iron to remain in the combined state in a way favorable to the dilatation in question. Throughout the process of cooling carbon and iron at any place within the metal are united in conformity with the given degree of carburation and with the strain there experienced. In the cold metal, at the given place, strain is to a certain extent permanent and independent of the surrounding medium of steel.¶ Hence if by gradual *secular* annealing of massive glass-hard steel, a sufficient number of carbon configurations are broken,

* Cf. Bull. U. S. G. S., No. 14, p. 88, 1885.

† Batchelder: Journ. Franklin Inst. (3), viii, p. 133, 1844.

‡ Marangoni: N. Cim., (3), v, p 116, 1879 (Rupert's drops of resin); De Luynes: Phil. Mag., (4), xlv, p. 464, 1873 (Rupert's drops of glass); B. and S: l. c.

§ This Journal, xxxi, pp. 441, 443; xxxii, p. 191, 1886; xxxiii, p. 33, 1887: Bull. U. S. G. S., No. 27, pp. 30 to 50, 1886.

‖ B. and S.: this Journal, III, xxxiii, p. 30, 1887.

¶ Bull. U S. G. S, No. 35, p. 42, 1886. Structure studied by the density method. Shells consecutively removed by galvanic solution.

stress may increase to an intensity sufficient to rupture the metal explosively.

In our earlier papers on this subject Dr. Strouhal and I were much puzzled to know whether the temper-strain, and in general the phenomena of annealing, were to be interpreted physically or chemically; whether annealing was a case of viscous subsidence of a mechanical temper-strain; or a mere case of decomposition of chemical hardness. In the light of the present advanced conceptions, this distinction is superfluous. It makes no difference whether the configuration breaks up into parts chemically different (as carbon and iron (say) in steel), or into parts chemically though not structurally identical (as in homogeneous metals.) Viscosity is conditioned by the degree of instability. Again it is clear that the principles which account for the subsidence of the mechanical strain, will also account at once for such chemical decomposition as is here in question; the difference in the two cases being vested in mere details of molecular mechanism. §§ 13, 14.

16. However complex the nature of the temper-strain in steel may be, the behavior of hard steel, when subjected to the influence of temperature, offers sufficient proof of its occurrence. The laws of annealing hard steel* are as follows:

(1) The annealing effect of any temperature acting on glass-hard steel increases gradually at a rate diminishing through infinite time; diminishing very slowly in case of low temperatures ($< 100°$); diminishing very rapidly at first and then again slowly at high temperatures ($> 200°$); so that the highest and hardest of the states of temper possible at any given temperature is approached asymptotically.

(2) The ultimate annealing effect of any temperature (time $= \infty$), decreases at a retarded rate with temperature, and practically reaches the limit of variation below 350°.

(3) The ultimate annealing effect of any temperature, $t°$, is independent of the possibly pre-existing effects of the temperature $t'°$, and is not influenced by subsequent applications of $t'°$, provided $t > t'$. In case of partial annealing at $t°$ (time finite), this law applies more fully as the ultimate effect of $t°$ is more nearly reached.

Postulating the strain discussed in § 15, these laws follow at once from Maxwell's theory; and the explanation (*mut. mut.*) is identical in character with that given in §§ 9 to 13, with reference to the applied torsion strain. Inasmuch as annealing is accompanied by chemical decomposition, the conditions under which the temper strain is reduced are those of § 13.

The third law of annealing asserts that the heat effect is analytic, but not in the same degree synthetic. The carbon

* Phil. Mag., V, viii, p. 341, 1879; Bull. U. S. G. S., No. 14, p. 195, 1885.

configuration definitely broken up by annealing, does not recombine on cooling. In pure metal, and up to a certain limiting (small) stress, configurations broken up by stress may recombine when stress is released or reversed. § 17.

If degrees of temperature be replaced by arcs of permanent set (*mut. mut.*), then these laws apply at once to motional annealing as defined in § 8*b*.

17. In certain comparisons between the strain effect exhibited by glass and by steel,* we were led both by gravimetric and by polariscopic observations to this distinction: the strain in hard steel is very perceptibly affected by annealing temperature as low as 50°, whereas in the case of quenched glass (Rupert drop), perceptible annealing is incipient only at 200°. The bearing of this result on the present discussion is manifest: the difference of behavior is due to the absence in glass of anything equivalent to the unstable carbon configuration in hard steel. The case of glass is nearly that of soft steel, and the behavior as regards viscosity in these two instances are similar.

Schrœder's† important result has relevancy here: in the case of hard drawn wire (Ag, Fe, german silver), minimum viscosity is found associated with maximum susceptibility to temperature. This is the general deduction from steel, for varying intensities both of temper strain and of drawn strain. § 13.

18. Following the suggestion of § 14, it may be inferred that in case of very complex molecular structure, instability of configuration will be a more probable occurrence, than in the case of simple bodies, *cæt. par.* Complex structured matter may be looked upon as a solidified mixture of homologous chemical series, with a predominating member to give the substance character. Conformably with this view the complex organic solids‡ like silk, ebonite, show more pronounced viscous deformation than metals or mineral solids. These known facts are thus in general accordance with the present theory. Nor is it remarkable, that a complex substance like glass, lies somewhere between hard steel and soft steel, in the scale of viscosity.

On the other hand, when the atoms of the molecule are all alike, and the structure of the substance is essentially atomic, we meet conditions favorable to permanent set. This is probably the case with many metals.

19. Maxwell's theory lends itself at once to the explanation of superposition (perfect or imperfect) of viscous motions, inasmuch as the interpretation given is independent of the special peculiarity of the strain to be discussed. I will adduce a few magnetic results which bear upon this point.

* B. and S.: this Journal, xxxii, p. 185, 1886; xxxi, p. 451, 1886.
† Schrœder: Wied. Ann., xxviii, p. 369, 1886.
‡ Cf. Kohlrausch: Pogg. Ann., cxxviii, p. 414, 1866, and many others.

Considering the permanent effects of temperature on the residual magnetic induction of hard saturated steel, Dr. Strouhal and I* found it necessary to discriminate between two species of magnetic loss:

(1) The direct effect due simply to thermal action on the magnetic configuration;

(2) The indirect effect, due to the action of temperature in producing mechanical annealing.

These two kinds of loss of residual induction often occur together. Considered separately the latter, *cæt. par.*, is very decidedly the greater in amount, and its character fully typified by the concomitant phenomenon of mechanical annealing. The former (1) is not only much smaller in relative magnitude, but subsides completely within a much smaller interval of time. In general, the occurrence of permanent magnetism in hard steel, in its thermal relations is subject to nearly the same laws of variation as those adduced in §§ 9 to 13, for ordinary mechanical strains. Instability of the carbon configuration is more seriously detrimental to magnetic permanence than is instability of thermal configuration.

If the unstable carburation configuration be removed by thorough annealing at 100°, then the cold hard re-saturated magnet must show exceptionally good magnetic stability as regards the effects of mean atmospheric temperature. If the saturated magnet is again thoroughly annealed at 100°, the exceptionally good magnetic stability in question is even further enhanced, because the magnetic configurations unstable as far as 100°, have now also been removed. Experiment shows the second magnetic loss to be relatively small. The rods carry the maximum of permanent hardness and the maximum of permanent magnetization as far as 100°. This process of consecutive annealing is the one we proposed when the magnets made are to withstand the effects of atmospheric temperature, of percussion, and of secular time.†

20. In the above paragraphs I have referred to thermal, carbon, and magnetic configurations, using the adjectives merely to designate the chief cause of the instability under special consideration, whereas the configurations themselves were not necessarily different. In the same way I contrasted thermal and motional instability. Thus a carbon and a thermal configuration may be one and the same grouping, considered from different points of view; so may a thermal and a magnetic configuration. The latter phrase is used advisedly, and the rod showing residual magnetic induction supposed to consist of configurations of all degrees of magnetic stability, as well as

* S. and B.: Wied. Ann., xx, p. 662, 1883.

† Details in Bull. U. S. G. S., No. 14, chapter VI; or l. c.

in all degrees of magnetic intensity. Stability and intensity are the qualities which in the present case correspond to stability and strain, respectively, in the above configurations.

Magnetic stability decreases from hard to soft and from soft steel to soft iron, following therefore the inverse order of viscosity; and its character too is different from viscosity, the tendency being toward sudden magnetic changes, even when the cause of such change is superinduced by heat. Cf. § 19.

The mean magnetic intensity of the configuration must depend on the dimensions of the saturated rod. In the normal case of linear rods this magnetic intensity increases from hard to soft steel* and from steel to iron. Hence from one point of view carbon configurations interfere with the occurrence of intense magnetic configurations; from the other point of view magnetic intensity increases in the direct order of viscosity, or stability of molecular configuration.

Among methods for elucidating the nature of the magnetic configuration, a comparison of the effect of a magnetic field on torsional rigidity is probably best. Extending the classic researches of G. Wiedemann,† I commenced a series of such measurements. In the case of a given field of great intensity, if two identical iron wires, respectively magnetic and unmagnetic, be counter-twisted to the same maximum shear (obliquity of external fibre, $\omega = \cdot 003$, say), then the product of the detorsion due to longitudinal magnetization and the diameter of the wires is constant and equal to the product of the shear and the magnetic coefficient of rigidity. This remarkable relation implies that the increment of the twisting couple evolved by magnetization increases as the third power of the radians, *cœt. par.*

21. Summarizing the results of the above paragraphs, I believe the statement of § 2 to be fully verified. I have shown that the effect of distributing unstable molecular configurations uniformly throughout the substance of a rigid metal, like steel, is analogous to that of dissolving molecules of acid or of salt in a non-conductor like water. These added molecules are the unstable groups with which Clausius's theory deals. In both cases the effect produced is proportional to the number of unstable groups distributed. If the number be sufficiently increased, the medium will ultimately be a viscous fluid in the one case, and an electrolytic conductor in the other. At the outset, pure water typifies the rigid solid.

* S. and B.: Wied. Ann., xx, p. 621, 1883.

† Wiedemann: Electricität, III, p. 683 to 698, 3d ed., 1883; Barus: this Journal (III), xxxiv, p. 180, 1887. I believe my researches are the first attempt to interpret these relations quantitatively, and they lead to the law expressed in the text. Other results I will communicate later.

The applied stress imparts a permanent strain to the solid. Viscous deformation is therefore accompanied by a residual phenomenon, which manifests itself when the applied stress is reversed or removed.* In liquids acted on by an electromotive force, the analogous reaction is the reciprocating force of galvanic polarization.

Again, Clausius and Maxwell's theories mutually sustain each other. For if the conception, that in a solid molecular configurations are present in all degrees of stability, is necessary to explain the behavior of strained solid matter, it follows that configurations of more pronounced instability will be present in electrolytic systems. Conversely the fact that many solids can be electrolyzed, points to the occurrence, in these, of a very advanced state of molecular instability. To take the concrete example of glass, the same molecular mechanism which at 300° promotes electrolytic conduction, when the solid is influenced by electromotive force, manifests itself at low temperatures as the viscosity of the solid under stress.

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ART. XX.—*On the Origin of Primary Quartz in Basalt;*†

by JOSEPH P. IDDINGS, of the U. S. Geological Survey.

A VERY interesting suite of volcanic rocks has recently been collected in the Tewan Mountains, New Mexico, by Major J. W. Powell and Mr. William H Holmes.

The collection, though not a large one, embraces several varieties of rhyolite and obsidian, with numerous forms of andesite and basalt. The whole group constitutes a graduated series of varieties, which range from rhyolite through andesite to basalt, with two slight interruptions, at dacite and olivine-bearing hypersthene-andesite. The general characters of the minerals and of the rocks themselves correspond to those of the volcanic rocks occurring throughout the Great Basin‡ of Utah and Nevada, and of those forming the volcanoes of the Pacific coast,§ and of the Republic of Salvador, C. A.‖

Without entering upon the study of all of these rocks, a description of which will be found in a forthcoming bulletin of the U. S. Geological Survey, it is the intention of the present paper to describe certain specimens of basalt which

* Kohlrausch: Pogg. Ann., cxxviii, p. 419, 1866.

† Read before the Philosophical Society of Washington, April 29, 1888, and published by permission of the Director of the U. S. Geological Survey.

‡ Hague and Iddings, this Journal, vol. xxvii, June, 1884.

§ Ibid., vol. xxvi, Sept., 1883.

‖ Ibid., vol. xxxii, July, 1886.

exhibit a remarkable number of porphyritic grains of quartz and to offer some explanation of its occurrence.

The basalts in question occur in the vicinity of Rio Grande Cañon. Those which form the second and fourth ledges from the top of the wall of the cañon are very much alike; they are light gray, fine grained, dense rocks with small porphyritic crystals. In thin section they are found to be holocrystalline, with much lath-shaped plagioclase and less augite in grains and stout crystals, besides magnetite and much colorless olivine in crystals and grains. There are a few porphyritic crystals of olivine and augite, and very abundant microscopic needles of apatite.

Seven other specimens of basalt were collected from a large flow, covering the country for four miles; two of them are light gray and dense; three are greenish black and dense; and two are dark red and vesicular. All are very fine grained.

The light gray basalts are somewhat like those forming the two ledges on the cañon wall, but carry more porphyritic olivines, besides abundant, small grains of crackled quartz.

These quartz grains are surrounded by light green shells, which are composed of microscopic augites. In some cases the shells cover the quartz grains on the surface of the rock; in others, especially on weathered surfaces, the quartz has dropped out, leaving the augite shell adhering to the rock. The quartz grains are distributed through the rock quite as uniformly, though not so abundantly as are the crystals of olivine.

In thin section these two specimens of basalt are alike and resemble those from the cañon wall, except that they are slightly coarser grained. They are holocrystalline, and are composed of lath-shaped and tabular plagioclase, light violet-brown augite in crystals and grains, with magnetite and much olivine in grains and porphyritic crystals. None of the quartz grains appear in the thin sections of these two specimens, but the augite rings and clusters indicate where they were located before the grinding of the sections.

The three specimens of greenish black basalt also exhibit macroscopic olivine and abundant quartz grains. The quartz is more compact and freer from cracks than in the previous specimens.

In thin sections, this form of the basalt has the same micro-structure as those just described, but is finer grained and contains more augite. The olivine is partly altered to dark green serpentine. In one of these thin sections there are seven grains of quartz or indications of their former presence, in another section two, and in the third there are ten.

The red, vesicular variety also bears many porphyritic grains of quartz. On the surface of one side of a small specimen $7{\cdot}5^{cm}$ long by 6^{cm} wide, there are 75 grains, and they are not especially abundant in this particular specimen.

In thin section these red varieties resemble the general microstructure of the gray, compact ones, but they do not appear to be holocrystalline; there is probably a little glass present. The rocks are filled with red oxide of iron, which also colors the margins of the porphyritic olivines. They contain a little more augite than do the gray varieties. Most of the quartz grains have dropped out in grinding, but fragments remain, and the augite rings indicate where they were once located.

As to the nature of the quartz which forms these porphyritic grains, it is evidently not an alteration product of other minerals nor an infiltration product, for the rocks are quite fresh and exhibit a very slight alteration on the surface of the olivines. On the contrary, the quartz grains undoubtedly existed in the rock-mass in their present form previous to the final consolidation of the magma. For each grain is closely surrounded by a shell of augite crystals, intimately connected with the enclosing rock-mass.

This augite shell forms a narrow border or ring in thin section, and is composed wholly of crystals of augite radiating from points along the side of the rock-mass toward the quartz. The augite crystals crowd against the surface of the quartz grains, but there is no line of demarcation between them and the rock-mass; the outside augites lie among the feldspar and magnetite individuals and take part in the general structure of the rock. In the coarser grained varieties the feldspars sometimes enclose a number of the augites situated on the outside of the shell, thus demonstrating that the augite shell existed prior to the final consolidation of the rock.

The substance of the quartz composing these grains is perfectly pure, and free from inclusions of gas, fluid or glass; in one instance there was a minute crystal of zircon. Each grain is a single individual, with uniform optical orientation throughout its substance. Occasionally two individuals are in juxtaposition. But they are never made up of aggregates of small grains, the form which secondary quartz usually assumes. The grains are rounded or subangular.

The substance and shape of the quartzes are like those of the porphyritic quartz grains in other volcanic rocks when they are free from inclusions, as often happens in rhyolites. They are not like the quartzes of granites and gneisses or of sandstones, which are more or less filled with inclusions of gas and fluid, and frequently with individualized inclusions.

It is evident, therefore, that the quartz grains in these basalts are primary constituents of the rock; that they are more like the porphyritic quartz secretions of other volcanic rocks in their microscopical habit than like fragments of quartz from granitic or gneissic rocks or sandstones.

Moreover their mode of occurrence in these particular basalts militates against the theory that they may be fragments of foreign rocks which have been caught up by the basalts during their eruption. For they are uniformly and intimately distributed through each of the seven hand-specimens which were collected from different parts of a large basalt flow, and represent portions of it which differ in crystallization and general habit. Furthermore, the grains are isolated individuals and not clusters and never exhibit indications of having been crystallized together with other minerals. They have every appearance of being primary secretions or crystallizations from the rock magma.

Similar occurrences in other localities.

Mr. J. S. Diller (this Journal, Jan., 1887) has described the occurrence and distribution of very abundant quartz grains throughout the recent basalt flow near the Cinder Cone, ten miles northeast of Lassen's Peak, California. And his argument for the primary and essential nature of the quartz in this particular basalt appears to me to be conclusive.

Two new occurrences of quartz-bearing basalt may be described in this connection, as they go to show that such basalts are scattered over a large area of country, having been found in California, Nevada, Arizona, New Mexico and Colorado.

That from Arizona is a fine example of quartz-bearing basalt; it is a red compact rock from the cañon near granite tanks in the vicinity of Santa Maria Basin, and was collected by Mr. Clarence King. In the hand specimen the only porphyritic secretions are rounded grains of glassy quartz from one to eight millimeters in diameter, together with somewhat smaller olivines. The quartz grains are so numerous that one small specimen about 6 cm. square shows as many as 30 grains on all its surfaces.

In thin sections the basalt is glassy, with abundant lath-shaped plagioclase and much red oxide of iron scattered through it, which obscures the other constituents. The ground-mass bears small porphyritic crystals of light green augite and olivine. In the dense specimens, the olivine is partly fresh and colorless, partly colored orange and red. In the porous specimens, the olivine has been entirely removed, leaving its

characteristic outlines marked by iron oxide. The augite is more or less reddened.

The quartz is the same in both varieties. It forms rounded and subangular grains, of very pure substance, almost free from inclusions. The few inclusions observed consist of colorless glass, in one instance gas, besides a small zircon and an apatite.

In only a few instances do the quartz grains possess a continuous shell of augite crystals. Most of the grains are bounded directly by the groundmass of the rock, or have a fragmentary augite shell which is sometimes separated from the quartz grain by red glass, sometimes by a strip of groundmass whose flow structure indicates that it has forced its way between the augite shell and the quartz grain.

Fragments of augite shells are observed at some distance from the quartz, or even entirely isolated in the rock mass, from which it appears that the quartz grains were at one time surrounded by a shell of augite, as in most other occurrences of quartz-bearing basalt, but that in this instance the subsequent movement of the magma broke the shells and dislocated them.

The second occurrence to be described is that of a dark colored, fine-grained basalt from Elk Head Creek, at the southeast base of Anita Peak, 15 miles northeast of Hayden, Colorado, in which porphyritic quartz grains are very abundant. Dr. Whitman Cross kindly furnished me with the thin sections of this rock for study and description. They present two modifications of the basalt, and show that the rock is partly altered, the olivines having been converted into serpentine, which is disseminated through the rock. The rock resembles the basalt from the Rio Grande cañon, N. M., in mineral composition and structure, but the quartz grains, which are very abundant, have a somewhat different microscopical character. They are surrounded by an augite shell in every case. But the shell is quite thin and its connection with the quartz substance is more intimate. In places the augites penetrate the quartz substance. In some instances the quartz exhibits sharp-edged crystal boundaries. The quartz grain is sometimes made up of two or three individuals crystallized together. The inclusions are numerous and consist of gas cavities and less abundant glass inclusions, besides zircon and apatite. The microscopical character of the quartz resembles that of certain porphyries.

Its primary nature is shown by the presence of glass inclusions and the encircling shells of augite, and by its uniform distribution through the rock. The existence of crystal boundaries shows that there was little if any resorption of the quartz

by the surrounding magma. The enclosure of augite crystals near the margin of grains containing glass inclusions indicates that the crystallization or secretion of the quartz took place in a molten magma in the presence of augite crystals similar to those forming the enclosing shells.

Quartz grains occur in the same manner, but to a much less extent, in some of the basalts near Eureka, Nevada. They are very abundant in certain basaltic rocks from the neighborhood of Crescent and Whitehead Peaks and Camel Mt., Colorado.

Possible origin of the porphyritic quartz.

Exceptional occurrence.—The occurrence of primary quartz in more or less rounded grains in basaltic rocks is exceptional, and contrary to the laws which appear to govern the development of the mineral constituents of volcanic rocks. The minerals developed being the result of the chemical affinities inherent in a complex solution of silica, alumina, with certain alkaline earths and alkalies (mainly iron, lime, magnesia, soda and potash), between the various demands of which there must be a mutual accommodation, it is evident that the resulting minerals must be those which under the conditions attending their crystallization satisfy all the chemical demands imposed by those conditions.

Limited variation of conditions.—That a change in the conditions under which crystallization takes place in a mixed solution affects the nature of the crystallization is well known, and has been demonstrated experimentally. From the generally uniform nature of the crystallization of most volcanic rocks, the correspondingly uniform conditions attending their crystallization are indicated. Where variations in the products of crystallization occur, the conditions effecting them may often be recognized. Hence, variations from the general order and nature of crystallization within certain limits have become generally accepted facts, so that no one expects the mineral composition of rocks to be in rigid accord with their chemical composition within these limits.

An exception emphasizing greater variations.—While in the great majority of cases the mineral composition of volcanic rocks indicates a generally uniform range of conditions which must have attended their consolidation, yet there are exceptions to the ordinary grouping of minerals in these rocks that emphasize the influence of certain attendant conditions, which must be regarded as physical. An instance of this is the mineral association in the lithophysæ of the rhyolitic obsidian from Obsidian Cliff, Yellowstone National Park, and from Cerro de las Navajas, Mexico. These holocrystalline

portions of the acid lava are composed of alkali-feldspar, quartz, tridymite and fayalite, an iron olivine. The latter mineral is in very small amount compared with the free silica, quartz and tridymite.

Influence of absorbed water.—In a paper on this occurrence (this Journal, xxxiii, Jan., 1887) I have discussed the matter at length, and after calling attention to the experiments of M. Daubrée on the action of superheated steam on acid glass, and to the experiments of others who have undertaken to produce these minerals artificially, I arrived at the conclusion, that this anomalous association of primary igneous minerals was most probably brought about by aqueo-igneous action, induced by the influence of water vapor absorbed in the molten glass. The strong mineralizing influence of the water vapor under such conditions becoming apparent both in the structure and composition of the lithophysæ and of the alternating crystalline and glassy layers in the laminated lithoidal portion of the same flow of lava. For in the latter case the thin horizontal laminæ of the magma in any particular portion of the mass must have been subjected to like rates of cooling and similar pressure, yet these laminæ solidified alternately holocrystalline and glassy.

Comparison of exceptional occurrences.—The occurrence of iron olivine in a rhyolite with 75 per cent of silica and less than 2 per cent of iron oxide is as remarkable and as exceptional as that of quartz in the form of porphyritic secretions in basalt. They are both of the same kind, in that they are the occurrences of extremely acid and basic silicate minerals together in rocks, where we are generally accustomed to see silicate minerals of intermediate or of more closely related composition.

In the first instance, however, most of the conditions under which the minerals crystallized can be surmised, but in the second case there is much more uncertainty. For the quartz was evidently crystallized in some early period in the history of the rock, when the conditions then existing made its separation from the magma necessary.

Indications of altered physical conditions.—From the rounded form of the quartz grains it is probable that the quartzes were being resorbed by the basic magma when the final solidification of the rock took place.

A similar resorption of porphyritic minerals, which have crystallized in an earlier period of a rock's existence is of common occurrence in nearly all volcanic rocks, as for example, partly resorbed hornblendes and feldspars, and the rounded quartzes of rhyolites and porphyries. And the idea that these phenomena indicate changes in the physical conditions and not

in the chemical composition of the magma is a generally accepted one. What some of these changes of condition probably were may be indicated by the following considerations.

Consideration of possible changes of physical condition.—If we conceive of a molten, viscous magma situated at a great depth beneath the earth's surface, the two factors which at first appear to have the greatest influence on its existence as a plastic or molten magma are *temperature* and *pressure.*

Influence of temperature.—Other things remaining the same, the magma will be more plastic the higher the temperature, and with a decrease of temperature below a certain point consolidation will take place.

Consolidation under these circumstances would undoubtedly produce crystallization, as a rapid chilling at great depths within the earth is scarcely conceivable. However the nature of the crystallization would vary within certain limits with the rate of cooling.

Influence of pressure.—If, now, the temperature remains the same and the pressure varies, assuming that an increase of pressure diminishes the mobility of the molecules of the magma by condensing them, which from a theoretical standpoint appears the most rational supposition, and which has received support from the recent experiments of Dr. Wm. Hallock;* and it having been demonstrated that the silicate minerals† and glasses‡ belong to that class of substances which contract upon solidification, we should expect that an increase of pressure alone would tend to consolidate the mass. This is the conclusion reached by Reyer in his work entitled, "Beitrag zur Fysik der Eruptionen und der Eruptiv-Gesteine." Vienna, 1877, p. 119.

Increased viscosity.—Dr. Hallock's observations show that cubical, statical pressure, unaccompanied by heat, simply increases rigidity or viscosity. But that in cases where pressure is allowed to produce motion by the crushing or yielding of the molecules of a substance, the internal friction may generate heat enough to fuse the substance, that is, to reduce its rigidity or viscosity.

The solidification of a glassy, amorphous mass by increasing its viscosity might convert it into a solid glass or into a crystalline mass, according to whether the viscosity was suddenly increased or slowly increased. The changes being analogous to the rapid increase of viscosity by chilling, or the slower increase by gradual cooling, the latter allowing the molecules to arrange themselves in obedience to certain chemical affini-

* This Journal, October, 1887.

† Roth, Allg. u. Chem. Geol., Bd. II, p. 52.

‡ Lagorio, T. M. P. M., vol. viii, 1887, 510.

ties into crystallized minerals, the former preventing such an arrangement.

Moreover if, as Professor A. Lagorio has done in a recent paper (T. M. P. M., vol. viii, 1887, 421) we consider rock magmas as saturated solutions of silicate salts, and apply to them the law which Sorby deduced for aqueous solutions of salts, namely, that the solubility of those salts, which like the silicates expand upon solution and condense upon crystallization, is decreased by increasing pressure; or, in other words, that increasing pressure tends to crystallize such salts from solution; then an increase of pressure alone would induce the crystallization of certain silicate minerals from a molten magma, or might lead to the crystallization of the whole magma.

Unstable consolidation.—According to these views of the effect of pressure on the viscosity of magmas and on their crystallization, we should expect that an increase of pressure would lead to the consolidation of magmas at temperatures above their melting point for lower pressures. And we might therefore have a highly heated magma within the earth under such pressure that it exists as a solid mass, which may be either crystallized or amorphous, or partly crystallized and partly amorphous. Such a condition would be one of unstable consolidation.

Influence of water vapor—Another agent or force undoubtedly plays an important part in the liquefaction as well as in the crystallization of heated magmas. The influence of water vapor on the viscosity of lavas has been suggested long ago by Scrope and others, and of its part as the explosive agent in volcanic eruptions there can be little doubt. Its presence in larger or smaller amounts in almost every volcanic rock has often been demonstrated.

Eutectic substances.—The bearing of Dr. Guthrie's experiments with cryohydrates or eutectic substances upon this problem has been brought out by Professor J. W. Judd in a recent paper. (Geol. Mag., Jan., 1888.) The characteristic feature of these mixed compounds is that their melting point is considerably below that of the component substances; they, therefore, behave like alloys. Most of the substances experimented with were hydrates, of which niter is chosen as an example. Under ordinary conditions this substance melts at 320° C., upon the addition of 29·07 per cent of water it melts at 97·6° C. Hence a mass of niter within the earth would be solid at 300° C., but at the same temperatures upon the accession of 15 or 20 per cent of water it would be molten, or in a condition to become molten if the pressure did not prevent it. Professor Judd calls attention to the power of the water of hydration to lower the melting point of zeolites and siliceous

glasses, such as tachylites, hydrotachylites, palagonites, etc. Professor Lagorio states that the feldspars of the lime-soda feldspar series behave like eutectic substances.

Increased liquidity of magmas.—The increased fusibility of hydrated glass has been demonstrated by M. Daubrée (Études Synthétiques de Géologie Expérimentale. Paris, 1879, p. 161), and may be easily recognized in the case of obsidian carrying 0·5 per cent. of water, like that from Obsidian Cliff. When this is fused before an oxyhydrogen blowpipe it melts at something less than white heat to an inflated glass, which, at first, is quite fluid and flows away rapidly from the strong current of the blowpipe flame. After driving off all the water from this glass and allowing it to cool, a colorless glass is obtained which only melts before the same blowpipe flame at an intense white heat, and then forms a very viscous glass which moves sluggishly before the same blowpipe current.

Retarded viscosity and greater crystallization.—If we consider the influence of water-vapor in increasing the liquidity of molten magmas as simply a physical one, it must tend to increase the mobility of the molecules among themselves. One effect of absorbed water, then, would be to retard the increasing viscosity of a rapidly cooling magma, which might permit the crystallization of the more hydrated portions, while the less hydrated parts became too viscous and solidified as glass. A condition of affairs which undoubtedly existed in the obsidian magma at Obsidian Cliff, where holocrystalline areas occur irregularly scattered through glassy ones.

Different kind of crystallization.—It is to be remarked that the crystallization which was in this instance specially induced by the influence of superheated steam, differs from that which usually takes place in acid lavas upon cooling, and that the result was the production of extremely basic and acidic minerals by the side of one another, or the production of extremes. A result, which is in a measure, analogous to the dissociation of the base and acid of a chemical compound by heating. The absorbed water-vapor apparently weakened the affinity between the bases and the silica and permitted them to separate into more basic silicates and quartz or tridymite.

Potential mobility.—Exactly what influence absorbed water-vapor has upon deeply seated molten magmas we do not know, but it seems reasonable to assume that its physical influence is of the same kind as that upon molten magmas on the surface of the earth, for in the two cases the most noticeable difference is that of the pressure under which each exists. Hence we may assume that its most potent influence lies in the increased mobility, which it tends to impart to the molecules of the mass. But in a confined magma this must be combined with

an increase of pressure against and from the retaining walls, which pressure we have assumed tends to decrease the mobility of the molecules. And of course the actual mobility or liquidity of the magma will depend on the relation between these two tendencies, which, if balanced, will result in the storing up of potential mobility, which would show itself should the pressure be relieved.

Heated, hydrated magma under pressure; unstable rigidity.—We may then imagine a heated, hydrated magma within the earth under such a pressure that it has become solid, the rigidity being an unstable one; and we may further assume that this solidification is either to an amorphous, glassy mass, or to a more or less crystallized one, that is, to one which is wholly crystallized to an aggregation of minerals, or to one which is made up of crystallized minerals and rigid amorphous material; a glassy, porphyritic mass. Under these conditions the solid magma will possess a potential mobility or liquidity, which will exert itself to melt the solid mass, if the pressure is relieved or lessened, as may happen when the fracturing of the earth's crust ruptures the retaining walls and permits the escape of this pent-up body, stored with gigantic expansive energy.

Refusion.—The melting up of an unstable, solidified mass by the heat inherent in it would undoubtedly proceed differently in the different minerals or the glass composing it, some fusing more rapidly than others. The difference would be the greatest between anhydrous refractory minerals, like quartz, and hydrated glass, through which they might be scattered porphyritically. If the refusion is complete, nothing will remain to indicate a former state of solidification. If the process of fusion is checked by the cooling of the magma in consequence of its eruption through cooler rock masses, there might remain in the cooling magma remnants of the minerals previously existing in it.

Final consolidation.—Moreover it is evident that the nature of the minerals of final consolidation will be affected by the nature and amount of the minerals formed at the time of unstable consolidation which remain unmelted. If these are highly acid the minerals of final consolidation will be proportionately basic, and *vice versa.*

Application to quartz-bearing basalt.—Applying the foregoing general considerations to the occurrence of porphyritic quartz grains in basalts, it seems reasonable to suggest that the production of extremely acid and basic silicate minerals in deep-seated magmas may have been brought about, like their production in certain magmas after they have reached the surface, by the influence of absorbed water acting under favorable conditions of pressure and temperature, which combined to

solidify the magma more or less completely for the time being, but which, as the quartz grains themselves show, was an unstable solidification, which subsequently yielded to the potential liquidity of the magma, resulting in the partial resorption of the quartz crystals before the final consolidation of the rock to its present form.

Reyer, (l. c. p. 166), suggests that pressure and different degrees of saturation with absorbed water may lead to metameric processes. And also states that the development of quartz in rock magmas requires a considerable saturation of the magma with water.

Prof. Lagorio (l. c.) refers the concurrence of quartz and olivine in the same rock to the super-saturation of the magma with silica and magnesia, but this idea of itself is not sufficient to account for the occurrence of quartz in magmas with the normal basaltic composition, where it generally does not occur, as it is not sufficient to explain the occurrence of fayalite in rhyolitic obsidian, having 75 per cent of silica and less than 2 per cent of iron oxide.

Confirmatory observations.—If the foregoing explanation which refers the production of the quartz in these basalts to physical conditions apart from chemical ones is correct, we should expect to find such anomalous associations of minerals in other varieties of volcanic rocks, and should not expect to find a necessary correspondence in the chemical composition of all basalts which carry porphyritic quartzes. Nor should we expect to find the quartz-bearing varieties, which are exceptional, necessarily holding a definite relation in point of age to the other volcanic rocks with which they are associated. These expectations, I think, are realized by the following observations.

Porphyritic quartz in other volcanic rocks.—The first point is beautifully illustrated in the suite of rocks in the collection from New Mexico, for it shows that similar quartz grains occur in almost all of the varieties of volcanic rocks from this region, and that their occurrence is not uniform throughout the series.

Thus in most of the rhyolites rounded grains of quartz are very abundant, but in some specimens they are absent (obsidian and lithoidite). In the single specimen of mica-andesite they are wanting. In the hornblende-mica-andesites, some specimens show a considerable number of quartzes; one, a few, and others, none. In the hornblende-pyroxene-andesites, one specimen shows many quartz grains; others, considerable; and some, none. Of the five specimens of pyroxene-andesite, one shows a few grains of quartz; the rest, none. And of the twelve specimens of basalt, seven show much quartz; the others, none.

Another group of volcanic rocks, specially characterized by abundant rounded grains of quartz, occurs in the vicinity of Crescent Peak, Colorado. The group embraces basalt, andesite and possibly trachyte. These all bear rounded grains of quartz, and some of the olivine-bearing varieties also carry hornblende paramorphs, which furnish additional evidence of a change of physical condition from one which induced the crystallization of certain minerals, to a later one, in which they were partially resorbed.

Chemical similarity of basalts with and without quartz.—That the chemical composition of quartz-bearing basalts is not characteristic of a particular modification of rock magma will be seen from the accompanying analyses:

	I.	II.	III.	IV.	V.	VI.
SiO_2	52·27	52·37	51·57	52·38	57·25	56·28
TiO_2	1·49	1·60	1·43	1·22	0·60	0·84
Al_2O_3	17·68	17·01	17·72	18·79	16·45	14·23
Fe_2O_3	2·51	1·44	6·24	2·88	1·67	4·69
FeO	5·00	5·89	1·78	4·90	4·72	4·05
MnO	0·23	0·32	0·45	0·18	0·10	0·16
CaO	8·39	7·59	8·82	7·70	7·65	7·94
MgO	6·05	6·86	4·91	4·91	6·74	6·37
BaO	0·06	0·06	0·16	0·11	0·00	----
					SrO tr.	
K_2O	1·58	1·59	1·99	1 76	1·57	1·23
Na_2O	4·19	3·51	3·59	3·99	3·00	2·98
Li_2O	----	----	----	----	0·00	0·01
H_2O	0·82	1·29	0·64	0·53	0·40	0·93
CO_2	tr.	0·37	0·58	----	----	----
P_2O_5	----	----	----	0·56	0·20	0·40
Cl	tr.	tr.	----	----	----	0·17
SO_3	----	----	----	----	----	tr.
	100·27	99·90	99·88	99·91	100·35	100·28

I. Quartz-bearing basalt, Rio Grande Cañon, N. M. (L. G. Eakins.)
II. " " " " " "
III. " " " " " "
IV. Basalt without quartz, " " " "
V. Quartz-bearing basalt, Cinder Cone, Lassen's Peak, Cal. (W. F. Hillebrand.)
VI. Quartzose diorite. Electric Pk., Yellowstone Park. (J. E. Whitfield.)

The first three are of three forms of quartz-bearing basalt from Rio Grande Cañon; the first is a light gray dense basalt; the second, a greenish black, dense basalt; and the third, a dark red vesicular basalt. They have practically the same composition with slight variations. The higher oxidation of the iron in the red rock is indicated by the high percentage of ferric oxide in analysis III.

The fourth analysis is of a gray, dense basalt from Rio Grande Cañon, which resembles the basalt from which the first analysis was made, except that it exhibits no quartz, either in macroscopic or microscopic grains. These four are normal basalt analyses resembling one another as closely as analyses of

similar rocks usually do. There are no greater differences between the analysis of the variety without quartz and those of the quartz-bearing varieties than there are between the analyses of the three quartz-bearing varieties. So that the occurrence of the quartz in this instance cannot be ascribed to anything exceptional in the chemical composition of the magma.

Chemical differences between basalts with quartz.—The fifth analysis is that published by Mr. Diller in the paper already cited. It shows a different chemical composition for this form of quartz-bearing basalt, which is more acid than typical basalt, and corresponds more closely to some andesitic forms of volcanic rocks.

It is probable that additional analyses of other quartz-bearing basalts will show as great a variation in their chemical composition as exists between that of basalts free from quartz grains.

Different mineral development of chemically similar magmas.—The sixth analysis is presented for comparison with analysis V. It is that of a magma of very nearly the same chemical composition, slightly more basic, which has consolidated under different conditions. It may serve to illustrate two points: first, the mineralogical extremes to which chemically similar magmas may be developed. Second, the possibility of a basaltic magma having existed at some previous period in a condition of unstable consolidation, in which quartz might have been crystallized out. Analysis VI is of a coarse grained, quartzose diorite, perfectly fresh and unaltered, of quite recent geological age, and which is composed of plagioclase feldspar, quartz, hornblende, biotite and pyroxene, with accessory magnetite, apatite and zircon. The quartz is in considerable quantity, very much more than the amount of quartz observed in quartz-bearing basalts. The discussion of this diorite is reserved for another paper, which is in process of preparation.

Summary.

The principal points brought out in this paper may be briefly stated as follows:

The quartz-bearing basalt from Rio Grande Cañon belongs to a series of volcanic rocks, characterized by a variable amount of porphyritic quartz in rounded grains.

These quartzes are primary crystallizations from the molten magma, and exhibit no definite relation to its chemical composition.

Their production is to be referred to certain physical conditions attending some earlier period of the magma's existence.

From analogy with the occurrence of iron olivine in rhyolitic obsidian, it seems probable that the formation of primary quartz in basalt took place under the influence of water-vapor at a great pressure.

ART. XXI.—*Mineralogical Notes;* by GEO. F. KUNZ.

1. *Phenacite from Maine.*

IN May, 1888, some crystals of phenacite were found near Stoneham, Me., in a vein of coarse albitic granite,* associated with crystals of smoky quartz, topaz and muscovite. Some of the crystals were implanted on smoky quartz. A few of them were attached to the matrix by one of the rhombohedral faces so loosely that they could be removed without being broken. They were about thirty in number, lenticular in shape and measured from 3 to 12^{mm} across, and from 1 to 3^{mm} in thickness. They were all white or colorless, and had polished faces; the form being for the most part very simple. Figure 1 of the series from Pike's Peak, Colorado, described by Penfield,† is an exact counterpart of the more highly modified form.

Of the topaz there were found about a dozen crystals which had unfortunately been broken from the gangue. They were colorless, light-green or cherry colored on the outer sides and colorless in the center. The largest crystal measured $1\frac{1}{2}$ inches in height and thickness. Almost all the crystals contained irregular hollow spaces from 1 to 10^{mm} across. In habit the crystals closely resemble those from Cheyenne Mountain, Colorado.

It is through the courtesy of Messrs. E. D. Andrews, T. F. Lamb and N. H. Perry, that I have obtained the crystals and the facts in regard to their occurrence.

2. *Quartz Pseudomorphs after Spodumene.*

In 1887, at the spodumene locality at Peru, Maine, which has furnished tons of that mineral for commercial purposes, there were found some crystals in which the original spodumene had been almost entirely replaced by white quartz, with the exception of a white core of crystallized albite. These crystals are remarkable for the sharpness of the striated prismatic faces; the terminations are not so distinct. The surface of the crystals is covered with a coating of damourite. The alterations of quartz after spodumene are fully described by Julien,‡ from the granite veins of Hampshire County.

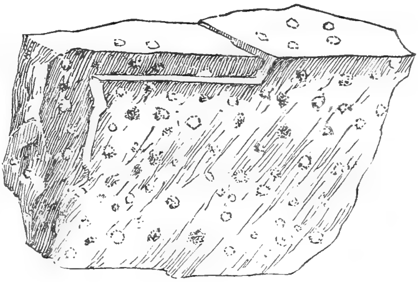
3. *A remarkable variety of transparent Oligoclase.*

In December, 1887, some specimens of feldspar were sent to me for examination by Mr. Daniel A. Bowman, who ob-

* This Journal, III, xxvii, 212. † This Journal, III, xxxiii, 131.
‡ Annals New York Acad. Sciences, vol. i, No. 10.

tained them from the Hawk Mica Mine, four miles east of Bakersville, North Carolina. They were found at a depth of 380 feet, and proved to be a variety of oligoclase, remarkable for its transparency. The clearest piece measured $3 \times 2 \times 1$ inches. In color, it is a faint window-glass green, and contains a series of cavities (see figure, natural size), surrounded and fringed by tufts of white needle-shaped microlites; these measure from 0·5 to $1{\cdot}5^{mm}$ in diameter and are quite round, resembling those occasionally present in the Ceylonese moon-stone.

1.



The wonderful transparency of the oligoclase and the white inclusions gives the whole mass a striking resemblance to the lumps of glass, so commonly obtained from the bottom of a glass pot. It was mistaken for this until the highly perfect cleavage was noticed; this is remarkable for the entire absence of the striæ so characteristic of the plagioclase feldspars.

Recently some material of a slightly different character has been obtained at the mine. Cleavage masses of white striated oligoclase three inches long were found, containing nodules about 10 to 15^{mm} square: these are as colorless and pellucid as the finest phenacite and are entirely free from the inclusions found in the greenish variety. This transparent variety like the other shows no striæ.

The following analysis was very kindly furnished me by Professor F. W. Clarke. It was made from the faint green variety and shows it to be a typical oligoclase. The specific gravity I determined to be 2·651:

SiO_2	62·92
Al_2O_3	25·32
Fe_2O_3	trace
MnO	trace
CaO	4·03
K_2O	0·96
Na_2O	6·18
Ign	·25
	99·66

4. *Apatite from near Yonkers, N. Y.*

I recently received from Miss F. R. M. Hitchcock, a fragment of an apatite crystal, which was found in the spring of 1887, in the tunneling at shaft 16, new Croton Aqueduct, Yonkers, Westchester County, N. Y. It is 10 by 15^{mm}, and is

merely a fragment perhaps of a crystal several inches in diameter. It is of a rich oily green, absolutely transparent and for perfection and transparency equal to anything ever found at the Knappenwand, Untersultzbachthal, Tyrol. Associated with the apatite was a granular epidote on which were some small dark green crystals of the same mineral.

5. *Cyanite from North Carolina.*

Mr. D. A. Bowman, of Bakersville, North Carolina, has kindly called my attention to some minerals from Bakersville, one of the most interesting of which is cyanite in distinct isolated crystals that for perfection, depth of color and transparency rival those from St. Gothard, Switzerland. They are found at an altitude of 5500 feet near the summit of Yellow Mountain, on the road to Marion, N. C., four miles southeast of Bakersville. They occur in a vein of white massive quartz in a granitic bluff, associated with almandite garnet of a very light pinkish purple color, but not transparent. The vein has a dip of 60° bearing N.E. and S.W. The color varies from almost colorless to deep azure blue, as dark as the Ceylonese sapphire. Some of the crystals were two inches long while a few were observed 15^{mm} in width, and 10^{mm} in thickness. No terminal planes were observed. Occurring in white quartz, they form beautiful specimens and the loose crystals were extensively sold for sapphire at Roan Mountain, the tourists' resort.

6. *Aragonite Pseudomorph.*

Among a collection of minerals sent to the Arizona Exhibition at New Orleans from Pima County, Arizona, was a crystal originally aragonite, which had been almost entirely changed and impregnated by oxide of manganese and red oxide of iron. It has an outer coating of white cacholong over some simple rhombohedral crystals, now entirely changed to an oxide of manganese. The crystal is hollow on top to the depth of three-fourths of an inch. The sides of the cavity are lined with cacholong, but the bottom of the cavity is partly filled in with a white compact chalcedony. The figure shows the crystal in natural size. The interior of the crystal is radiated, but is of a dark chocolate color and almost entirely altered to hematite.

2.

SCIENTIFIC INTELLIGENCE.

00. *Explorations of the Gulf Stream*, by Lieut. J. E. Pillsbury, U. S. N.—The Report for 1886 of the U. S. Coast and Geodetic Survey contains, in Appendix No. 11, a Report of new Explorations of the Gulf Stream illustrated with maps, which closes with the following conclusions (p. 289):

"I have to submit the following summary of my conclusions, based upon the information obtained during the two seasons' observations. The examination of the Gulf Stream currents having been made in March, April, May, and June, the conclusions may be incorrect for other seasons of the year, although there are no good reasons for supposing that such is the case except, possibly, in the amount of the variations.

(1) Between Fowey Rocks, Florida, and Gun Cay, Bahamas, the current varies daily in velocity, at times as much as $2\frac{1}{2}$ knots. The greatest velocity is generally about nine hours before the upper transit of the moon. The variations are most excessive on the west side of the straits and least on the east side.

(2) The average daily currents vary during the month, the strongest set coming a day or two after the greatest declination of the moon.

(3) The axis of the Gulf Stream, or the position of the strongest surface flow in passing this point, is $11\frac{1}{2}$ miles east of Fowey Rocks Light-House. The strongest surface current found here was $5\frac{1}{4}$ knots per hour; the least, $1\frac{3}{4}$ knots; and the average, $3\frac{6}{10}$ knots. The average current at other places on either side of the axis is as follows:

	Knots.
Axis of the stream, $11\frac{1}{2}$ miles from Fowey Rocks	3·6
$3\frac{1}{2}$ miles west, or 8 miles from Fowey Rocks	2·6
$3\frac{1}{2}$ miles east, or 15 miles from Fowey Rocks	3·2
10 miles east, or 22 miles from Fowey Rocks	2·8
17 miles east, or 29 miles from Fowey Rocks	2·4
24 miles east, or 36 miles from Fowey Rocks	1·8

(4) The wind probably retards or accelerates the velocity of the current. A northeast gale in the Atlantic will probably "break up" the water of the stream, lowering its velocity materially, and afterwards the flow will, by the reaction, be greatly increased over the normal speed. There is no evidence of any change in position of the axis of the stream due to the wind.

(5) Two days' observations off Jupiter Light, Florida, indicate the same daily variation as was found off Fowey Rocks, and the axis of the stream at this section is probably about 17 miles east of the light."

Appendix No. 12, in the same report, is a new and greatly enlarged review of the "Secular variation of the magnetic declination in the United States and some foreign Stations, by Charles A. Schott. It covers pages 291 to 407.

Obituary.

Henry Carvill Lewis.—Professor Lewis, of Philadelphia, died at Manchester, England, on the 21st of July in his thirty-fifth year. He was a graduate of the University of Pennsylvania, an active member of the Academy of Sciences of Philadelphia, and in 1883 became Professor of Geology in Haverford College. One of his earliest papers, if not the first, is a notice of the Zodiacal Light, giving the results of five years' observations; it was read before the American Association in 1880, and appeared in vol. xx (1880) of this Journal. He commenced his glacial investigations in 1879, in connection with the Geological Survey of Pennsylvania, worked on the same subject in 1885 and 1886 in Great Britain, and had intended to make observations the present season in Norway. The investigation of the "Terminal Moraine" from the eastern boundary of Pennsylvania (to which point it had been traced across New Jersey, by Professor G. H. Cooke), westward across Pennsylyvania, occupied him until the autumn of 1882, when his report of about 300 pages was presented for publication. It appeared in 1884, as No. Z of the Geological Series of the Pennsylvania Survey. In 1886 he read his paper on Glaciation in Great Britain before the British Association.

Professor Lewis was also a zealous mineralogist, and until recently had editorial charge of the mineralogical department of the American Naturalist. In 1886 he brought out his paper on the "Genesis of the Diamond," tracing it to eruptive rocks, and basing his views principally on the published accounts of the diamond fields of Southern Africa.

Mr. Lewis was an enthusiastic and energetic worker in Science, and promised to do much for its progress. He leaves a wife and one child.

James Stevenson.—Col. Stevenson died on the 25th of July. He was born in 1840, at Maysville, Kentucky. He was an early explorer of the Rocky Mountain region, and accompanied Dr. Hayden in his expedition as executive officer and manager. In 1872 he ascended the highest of the Teton Range, the Great Teton. He has been, since 1879, connected with the U. S. Geological Survey, engaged in making ethnological investigations and collections in New Mexico and Arizona. A very valuable report by him on the collections obtained in 1879 and 1880 is contained in the Report of the Secretary of the Smithsonian Institution for 1881.

Albert D. Hager.—Mr. Hager was associated with Professor Edward Hitchcock and Mr. C. H. Hitchcock in the Geological Survey of Vermont. Since 1872 he has lived in Chicago, where he died on the 29th of July. He was born at Chester, Vermont, in 1817.

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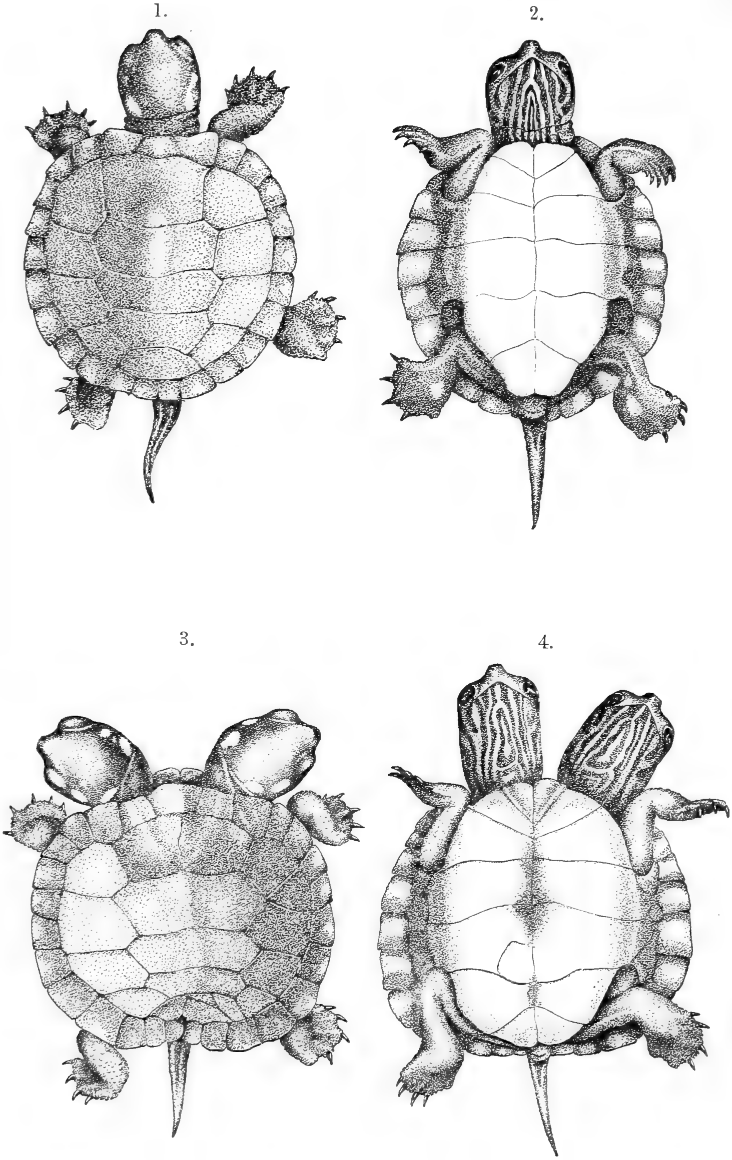


CHRYSEMYS PICTA.

Figs. 1, 2, normal form; 3, 4, form with two heads; enlarged one-third.

Drawn from nature by E. H. Barbour.

THE

AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

ART. XXII.—*On a young Tortoise, Chrysemys picta, with two heads;* by E. H. BARBOUR. With Plate V.

THE following is a brief description of a young two-headed tortoise, *Chrysemys picta*, which is a remarkably interesting specimen from the very perfection of its imperfection. It was found in the marshes bordering West River in New Haven, Conn., by Master Leighton Foster, the first part of June, and from appearances had been hatched but two or three days.

The single body, with the usual four legs and a tail, carries two equal, and in every respect, normal and well-developed heads and necks, which are throughout entirely free and distinct. The two heads see, hear, eat, drink, sleep, breathe, and move independently. See figures 3 and 4, and compare with figures 1 and 2, which represent a normal tortoise of the same age—about two weeks. The carapace, to external appearance, is well formed and natural, save that it is broader than long by nearly one-fourth, and its vertebral line is a little curved to the right, with the back slightly humped. But none of these are noticeable deformities, had it a single head. Its appendages are perfectly natural so far as their form is concerned.

This little monster still lives (Sept. 4), and has increased in size at least one-third during the past fourteen weeks. It is active and apparently healthy, and bids fair to survive this season at least. It eats voraciously when fed by familiar

hands; but a fly or cricket is often a bone of bitter contention. The first to seize its food becomes at once involved in a stubborn tug of war with its other self, which ends only when the morsel separates. The two heads eat with equal readiness, yet often the appetite of one is greater than that of the other. Sometimes one head turns slowly around and snaps at the yellow eye of the other, obviously mistaking it for something to eat. Of course the head and neck of the one assailed is straightway withdrawn into the common protecting shell, where they can find shelter, one at a time or together; but in the latter case it is plainly crowded, and the encroachment on tortoise prerogatives means a renewal of hostility, and a beating of their heads together till a compromise is effected. These little misunderstandings are always settled in a spirited way, and are exceedingly ludicrous. Although rather frequent, they never arise save when the two heads are disposed to withdraw to their shell simultaneously; at other times each in his turn enjoys the privilege. One often withdraws and sleeps while the other is perfectly wide awake. And then the one awake, looking about to the right and left, sometimes starts off vigorously, but only to find itself describing a circle, round and round as if on a pivot, for such in fact the sleeping side actually becomes. And generally it continues to use its two feet as best it can, scurrying around in an endless circle, until the sleeper, aroused by the commotion, puts out its head, looks about, and then shuffles off with its companion. There is no concerted action whatever in the use of the feet, as in the normal tortoise, which first puts one fore-foot forward and follows this with the diagonally opposite hind-foot, and so on. But, as should be expected, the two-headed tortoise, with its two ambulatory systems, puts out both fore-feet at once, leaving its fore-parts without support, so that they drop and rest on the plastron; then the hind-feet advance, and the hinder extremities, left in their turn without support, drop, and thus it advances by an awkward rocking gait.

But these twin heads have finally learned to adapt themselves in various ways to their circumstances. This is especially striking in the matter of walking. By repeated failures, each had discovered that when its companion sleeps, or is not disposed to move, any activity on the part of either is circumscribed by the narrow circle whose radius is the breadth of their common body. Accordingly, now, when either has made a few bootless revolutions, it stops short and extending its two feet laterally, seizes with its claws anything offering resistance, and so slowly and laboriously drags itself sideways, crab-like. By this device, to which they resort so repeatedly that it cannot be counted mere chance, they can travel on indefinitely.

When placed on smooth ground, free from grass and obstructions, their first manœuvre, after turning the right head to the right, the left to the left, is to start off resolutely in these two directions at once, the rather remarkable resultant of the two forces in opposite directions being a straight line directly backward; they make progress for a foot or two in the wrong direction, then agree on a course and start off together. In the grass or weeds they are quite helpless, because when a stalk of grass is encountered, one head chooses the right course, the other the left, that is, they straddle it, and being equals in strength, neither side succumbs, so they stand there tugging away until tired out.

It is interesting, though not surprising, that two heads so nearly one should have different temperaments. The right head, on most occasions, is the more timid and irascible, retracting or dodging at a passing fly, or the approach of a strange animal. The left head, on the other hand, seems bold and energetic. It is difficult to conceive of any two individuals, growing up under surrounding circumstances more completely identical than these. Yet, like the South Carolina negresses, called the Two-headed Nightingale, the difference in their dispositions furnishes new evidence that, though the origin and environments be precisely the same, the results are not necessarily so.

To what extent the digestion, respiration, circulation, and nervous systems are united or separate is at present only open to conjecture. The alimentary canals, in all probability, become united in one stomach after leaving the two necks, and remain so to the anus, which is single. I have noticed that while the two heads eat equal amounts, yet at one feeding the left head perhaps shows the greater appetite, at another time the other. But no risks can be taken by experimenting with such a pet, or we could feed one at the expense of the other for a short time. By watching the expansions and contractions of the throat, where the hyoid plays so important a part in chelonian respiration, we find that each of the heads breathes regularly, but independently, as much so as if they belonged to disconnected individuals. At regular intervals they can be seen opening their mouths and gaping, as if the supply of oxygen was insufficient, as it doubtless is. This is their only visible sign of weakness.

As already stated respecting the nervous system, it is perfectly patent that the appendages of the right and left sides belong to, and respond only to, their respective heads. So noticeable is this independence in the action of the four feet, which otherwise seem to belong naturally enough to the one carapace, that many who see its attempts at walking are led to

"wonder if the other legs of the double shell are not growing inside."

There seems to be absolutely no coöperation between the left side and the right, and yet they repeatedly start at the same time to do precisely the same thing, eat, swim, or walk. When by any mischance it falls over on its back, the two heads work in opposite directions to right the shell, and so without help it could never, like an ordinary tortoise, extricate itself from the predicament.

The length and flexibility of each neck shows it has the full number of cervical vertebræ, confluent at the first thoracic vertebra. In other respects its skeleton is quite normal. The dermal plates show a few unimportant variations. There is the usual nuchal plate in front on the middle line, and two pygal plates behind. Between these two points on either side are twelve marginal plates; the usual though not invariable number being eleven. On the right side an extra scute is wedged in among the costal plates, making five on that side to four on the other. The five vertebral or neural plates preserve their relative positions, but have somewhat distorted forms. The first of these is divided by a suture through its length. The fifth is composed of four small irregular plates, and presents a fissure where it did not unite on the middle line. The plates of the plastron show but one irregularity, a doubling of the gular plate. A suture is seen in the right femoral plate; and the right infra-marginal plates are united, the left separate; but these are not peculiarities however.

When the time arrives for the promised dissection of this curious little monstrosity, I shall hope to find anatomical peculiarities of some consequence.

Paleontological Laboratory, New Haven, Ct., Sept. 4th.

ART. XXIII.—*The Structure of Florida;** by LAWRENCE C. JOHNSON.

THE stratigraphy of Florida is as yet so little understood that any notes upon it may be acceptable.

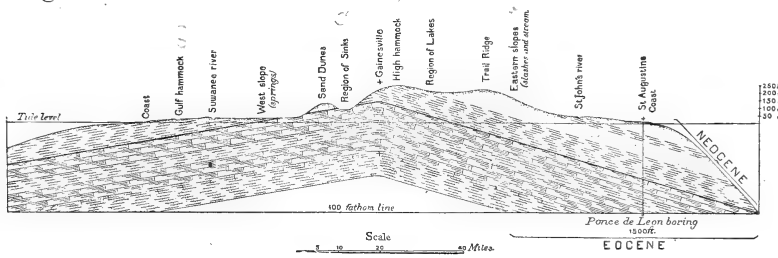
The facts in this contribution can best be made clear by a section across the peninsula through St. Augustine and Gainesville. By this it will appear that at least all the northern and middle portion of peninsular Florida may be divided longitudinally into four regions, plainly marked by surface indications: (1) the "Gulf Hammock" in the west, (2) a central

* Read before the American Association for the Advancement of Science at New York, August, 1887.

plain, or region of sinks, (3) the "High-Hammocks," or Lake region and (4) the "Eastern-slope"—or region of streams, tributary to the St. Johns.

The immediate coast on either side is not considered.

The turning point will be to understand the second,—the region of sinks.



In the figure, it is represented as a depression, though not always such. Westward it is bounded by a line of sand dunes, continuous at least from Sumter County northward beyond the Santafè River, whence it begins to curve more to the west, and becomes lost in other formations.

The eastern boundary of the central plain is, in places, sharply defined; for instance, at Weldon station on the Florida Transit Railway, which is given as the summit or highest point on the line between Jacksonville and Pensacola. This high ridge trends northward into Georgia in the direction of Dupont; and southward by many curves and scallops to the "Natural Bridge" on the Santafè—to Gainesville, to Okala, to Leesburg.

The third, or Lake region proper, begins at the Weldon ridge, and on that line of railroad, reaches to Trail-Ridge,—within eighteen miles of Jacksonville. Geographically it is easily defined. In Georgia it is in part represented by the Okefenoko swamp system; south of the St. Mary's River we have lakes, and the lakes of Florida are numerous.

Eastward of the elevated region of the Lakes,—the fourth division has a surface of thin sandy soils with many streams,—and with extended "Flatwoods" interspersed with "slashes" which give rise to streams. This is presented as a geological division, because it is believed to be constituted in the main of newer Tertiary formations, but being as yet unexplored, very little can be definitely said of it. Taking the data derived from the artesian wells bored at Palatka, St. Augustine, Jacksonville and other places, these Neocene deposits have an average thickness of about 300 feet.

Returning to the consideration of the second division: All later observations go to sustain the geological horizon assigned

to it in 1881 by Dr. Eugene A. Smith,—that it is of the upper Eocene, known as the Vicksburg stage. Confirming this determination was the opinion of Dr. Eugene W. Hilgard, and of Mr. Angelo Heilprin, who judged by the fossils submitted to them. The latter however, as I understand him, now expresses doubt, whether the true Vicksburg rock with *Orbitoides Mantelli* really belongs to these Florida localities. It seems he has seen specimens of a superficial formation found in many places, from as far south as Pemberton Ferry to as far west as Wakulla County, wanting, so far as he has observed, in *Orbitoides Mantelli*, but having two others, *O. ephippium* and *O. dispansa*, and sometimes associated with a foraminifer which he says is *Operculina complanata*, and with a Hemiaster.

Such rocks do seem in many places, especially toward the south, to constitute a thin upper layer, and always more or less silicified. There is no sufficient reason as yet observed, to regard it as more than an upper layer—similar to such superadded layers seen in Alabama at the Lower Salt Works on the Tombigbee River, described in Bulletin 43 of the U. S. Geological Survey.

Possibly these irregular deposits may be remnants of the Nummulitic limestone, which is really a stratum overlying the Vicksburg rocks, well seen at the old iron works near Levyville, Levy County At Levyville it is a beautiful soft porous building stone, about twenty feet in thickness, which was utilized in the erection of the Confederate iron-works. Often struck in the artesian borings and easily identified by the peculiar nummulites, it has a greater thickness under the Neocene formations to the east. In these western regions it has probably suffered general removal by erosion.

Apparently conformable in deposition with the Vicksburg stage the Levyville formation is evidently not identical with it; and demands a further investigation. It is a mistake however to suppose that this Nummulitic formation everywhere hides the Vicksburg rocks of the *Orbitoides Mantelli*, or ever did overlie the whole of it. Numerous are the exposures to prove the contrary. In very many places, especially in Alachua county and northward, the outcrops cannot be distinguished from the rocks of Vicksburg and of the Chickasawhay, Mississippi. Not often is it sufficiently exposed to the action of water percolating directly through the surface sands, to become silicified. Yet there are places where even this has occurred; notably at Payne's prairie.

Often therefore, it is quite a *rotten* limestone,—affording opportunity by its solution for the excavation of those underground passages for water, amounting sometimes to rivers,—which is one of the phenomena of Florida. The "Natural

Bridge" on Santafè River is an excellent example. In places above the surface over which runs the public road, there are old arches, once filled by the current of the river, before the excavation of the lower tunnels now occupied by it. The material of the present and of the old arches cannot be distinguished from softer varieties of the same formation in Alabama and Mississippi, which is true also of the harder material used as a building stone.

Some two miles south of the Natural Bridge and not far from the Noonanville road, though at an elevation considerably greater, in a quarry still used, is a stone exactly like that of which chimneys are built in Conecuh and Covington Counties, Alabama, and in Wayne and Jasper Counties, Mississippi. It is the same stone also that is used for like purposes in Marietta, Jackson County, Fla.

Another fact worth noting of this quarry near the Santafè, is that the Neocene formations to be mentioned farther on seem to rest directly upon this building stone, without the intervention of the Nummulitic limestone or of the usual layer of silicified rocks, common farther south and west.

Another locality like the *rotten* rocks of the Natural Bridge, yielding millions of *Orbitoides Mantelli* and *Pecten Poulsoni*, is the William's Sink near Noonanville. The "Big Sink" or "Payne's Prairie" near Gainesville is another—which has already been mentioned for the interesting fact of its silicifications. For miles to the south the low level country is covered with loose rocks and bowlders of the silicified upper layer. Particularly may this be seen at and around Aredondo, near which also is the "Hogtown Sink"—showing a perfect repetition on a larger scale of the facts of the "William's Sink."

Not to attempt to enumerate all the occurrences of such exposures, it will be sufficient to say that the most southern actually seen, are at Pemberton's, Pasco County, and on the head waters of Hillsborough River in Polk County, Sec. 27 and 28, T. 26, R. 23—which, till further advised, may be set as the southern boundary of Eocene exposures.

It might be objected that the "Gulf Hammock" region of the west has sinks as well as this central region. True, and there are also a few highlands and lakes at the west. But neither exhibits a fair and general average of the Gulf region. Instead of "Gulf Hammock" it might be called the "region of springs." In the lowest portions of it (and it is generally low) there are many of those great springs, which are the outlets of the underground rivers. In the central region there are no springs—no rivers. The Suwanee and the Santafè cut across it, but do not rise in it. All the other streams rising in Neocene sands are small and end in enormous cavities which swal-

low them up, to be seen no more, till they rise again in the Ocean, or by such outlets as Silver Springs to the east, and Tarpon and other great springs to the west.

The Neocene terranes of Florida begin somewhat farther west than the line assigned them on our latest geological maps. Instead of Trail-Ridge, they can claim the Weldon and Gainesville highlands for their western boundary.

A fair section, verified from several partial exposures, and many excavations and borings, gives us for the Gainesville highlands:

1. Unimportant and variable layer of detrital accumulations and soil .... 1 to	10 feet.
2. The "Chimney rock," or Waldo formation having Miocene fossils, and generally phosphatic, not less than 10 feet, and possibly 50, average	30 feet.
3. Ferruginous sands, with chalcedonized shells of Ostrea and others, and in places limonite	10 feet.
4. Greenish and buff clays—sometimes indurated, and sometimes with fossils ... 1 to	50 feet.
Total	100 feet.

Layer No. 1 requires no specific description. Where the sand is very deep the soil is usually thin. Where sufficiently thinned off to permit the influence of the underlying formation, the fine "high-hammock" lands are found.

Layer No. 2 in places called the "chimney-rock" from a popular use of one of its constituents—is the site and source of the phosphatic rocks of this part of Florida. In places it has suffered much erosion, and the reworked material has often been redeposited in beds of uncertain age, making a conglomerate with clay, bones, and nodules of the rock. Simmons's phosphate bed near Hawthorne is a good instance, and the "Devil's Mill-hopper" west of Gainesville is another. Undisturbed and *in situ*, among other places, it may be seen near Waldo, at old Fort Harlee in Preston's marl bed.

The fossils of this locality are innumerable, but mostly as casts of the interior of shells or moulds of the outer surface. Vertebrate remains are unchanged or only silicified, and so also are Ostrea and Pecten among invertebrates. Of the latter, easily recognized, are *Pecten Madisonius* and another large one; casts of at least two large Carditas; a large *Venus* very much resembling *V. mercenaria* but of coarser outlines; a very large Balanus, and many casts of gasteropods.

Layer No. 3, as said elsewhere, is the source of the limonite, and of the peculiar ostrea-chalcedonized—found in many

streams, and excavations from Georgia, as far south at least as Okala and Levyville. It yields many springs. Among these may be mentioned the "Magnesian Springs" of Simmons and Brown near Hawthorne. The current here often brings out fragments of shells and ferruginous particles. A great bed of these shells with limonite may be seen exposed in the run of Lochloosa Creek near the springs.

Layer No. 4—the buff and greenish clays—could seldom be seen. A similar clay, but possibly a reworked later deposit contains the great bone bed at Mixon's near Archer. These fossils are all vertebrate and all silicified. Similar deposits are found in many other places, and often as islands left by erosion, and always resting upon Eocene rocks. Similar fossils are found scattered (as already said) throughout layer No. 2, and possibly may be found in still newer formations farther south and east.

This about concludes the matter. The Waldo formation once understood, the stratigraphy of east and south Florida may be understood. This formation is the basis of the "high-pine" and "high-hammock" soils, and is one of the factors in the genesis of the lakes. The other factor is, of course, the underlying rotten limestone, of Eocene age, with its subterranean tunnels and rivers. To the last are due the sinks. Wherever there is a sufficient thickness of the overlying Miocene rocks and clays to choke up the sink, and arrest the drawing of the superficial layers into the great hopper-shaped centers of erosion, a lake is formed.

In the Central Lake Region, these bodies of water all approximate a funnel-form in depth and outline. Many of them have no superficial outlet.

To the extreme south and southwest, Florida has many other lakes not of this class and history: lakes which are all connected with the streams and rivers, and are but remnants of ancient lagoons and inlets of the sea of latest Tertiary and Quaternary times. These are all comparatively low lying, have firm bottoms of inconsiderable depth, and are not at all connected with the underground drainage of the Vicksburg rocks.

For this reason the high lake region is a good mark of Eocene limestone lying within about 100 feet of the surface; and the formation may be as safely located thereby as if there were manifest outcrops.

The southern lakes, like Thonotosassa, and Tohoptaliga, have for their bed another phase or stage of the Miocene, which for convenience may be called the Tampa formation, constituting so thick a layer that the influence of the underlying Eocene is not felt. The same is true of Tampa and Hills-

borough Bays. The upper end of old Tampa Bay is now in process of occlusion, and with a little more elevation will be a lake.

In the section exhibited by the figure at the head of this article (p. 231),—one or two later beds,—all of conjectural thickness—are represented as overlying the Waldo formation, at least in part. The borings for water at Palatka, at St. Augustine, at Jacksonville, give much certainty of a rapid dip toward the Atlantic, and of an increasing depth of the Neocene beds as we advance northward. The mouth of the St. John's or of the St. Mary's River will come in about the bottom of the ancient Miocene bight of the Atlantic which occupied so large a part of southern Georgia. Much further investigation and patient scrutiny will be required to ascertain the details of the depth and extent of these later formations, and to assign to each its proper horizon.

Art. XXIV.—*An Analysis of a Soil from Washington Territory, and some remarks on the utility of Soil-analysis;* by Edward A. Schneider.

The soil and rock, the analyses of which are given on the following pages, were kindly furnished to me by Professor E. W. Hilgard from his extensive collection of soil specimens, for which favor I offer him on this occasion once more my thanks.

The place of occurrence of these specimens is the Rockland Ridge, near "The Dalles," on the Columbia River, Washington Territory. The geological indications, as I have been told, were that the soil was formed "in situ" by disintegration of the rock. Comparative analyses have confirmed this supposition; still it is probable that the soil contains a small amount of constituents which do not form a part of the mother-rock; particularly noticeable among this class is mica. I am indebted to the kindness of Professor A. W. Jackson, of the University of California, for the petrographic analysis of the thin sections which I had prepared. According to the statement of Professor Jackson, the constituents of the Rockland Ridge rock are: "plagioclase, augite, apatite, magnetite, undifferentiated glass;" the rock is consequently, according to the same authority, an augite andesite.

The analyses of the mother-rock and of the soil disclosed the following results:

Analyses of the mother-rock and of the soil.

	By fusion.		By extraction with HCl.		
	Rock.	Soil.	Rock. finely	Soil. triturated.	Soil. untriturated.
Matters insoluble in HCl	----	----	75·41	71·42	71·87
SiO_2 soluble in Na_2CO_3	----	----	1·57	7·73	11·00*
Matters insol. in Na_2CO_3	----	----	63·84	63·69	60·87
Total SiO_2	50·85	58·16	----	----	----
P_2O_5†	0·76	0·43	0·76	0·43	0·36
SO_3	0·05	0·07	0·05	0·07	0·08
H_2O	0·34	1·77	0·34	1·77	1·77
K_2O	1·13	1·68	not‡	0·78	0·78
Na_2O	2·37	2·56	determined	1·02	0·67
CaO	9·33	4·57	6·29	3·02	2·48
MgO	5·57	1·99	3·42	not	·97
FeO	7·11	----	----	determined	----
Fe_2O_3	10·03	10·59	13·85	9·22	9·22
Al_2O_3	12·54	15·03	8·25	9·35	8·95
Org. matter	----	3·52	----	3·52	3·52
	100·08	100·37	----	----	100·67

Since a soil is a very complex mixture. I proceeded first of all to separate it as far as possible into its mechanical elements. For this purpose I passed the reddish brown soil consecutively through three different sieves. I obtained thus rock fragments $>2^{mm}\square$, fragments $<2^{mm}\square > \cdot 6^{mm}\square$, and a quantity of fine earth $< \cdot 6^{mm}\square$, which formed the bulk of the soil-specimen.

19·6987^{grm} of the fine earth dried at 100° were treated according to the directions of Professor Hilgard for the mechanical analysis of soils.§ I thus obtained

2·8500^{grm}	clay			14·46	per cent.
3·4232	sediment	$< \cdot 25^{mm}$	h. v.‖	17·38	"
·7125	"	·25	"	3·62	"
·7987	"	·5	"	4·05	"
1·9012	"	1	"	9·65	"
2·2637	"	2	"	11·49	"
2·7200	"	4	"	13·81	"
1·6850	"	8	"	8·55	"
1·5242	"	16	"	7·74	"
1·1617	"	32	"	5·88	"
·6382	"	64	"	3·24	"
19·6784				99·87	"

* It is possible that soda-solution dissolves more silica from the untriturated than from the triturated soil, because, during the process of boiling, it gets better access to each particle of the soil.

† By extraction with HNO_3.

‡ Alkaline chlorides—4·54 per cent (alkaline chlorides obtained by fusion =6·25 per cent.

§ This Journal, vol. vi, Oct., 1873.

‖ h. v. = hydraulic value.

or

I.	2·8500^{grm}	clay		14·46	per cent.
II.	3·4232	sediment < ·25^{mm} h. v.		17·38	"
III.	10·0811	"	·25^{mm} h. v.–8^{mm} h. v.	51·17	"
IV.	3·3241	"	8^{mm} h. v.–64^{mm} h. v.	16·86	"
	19·6784			99·87	"

These four fractions, obtained by mechanical analysis, represent the natural and characteristic subdivisions of this soil, as the general aspect, the microscopic examination and the chemical analysis have shown. They are described as follows:

I. *Clay;* has a brownish yellow color, and appears amorphous under the microscope.

II. *Silt,* or *sediments* < ·25^{mm} *h. v*; has a bright brick-red color. Under the microscope most of the soil-constituents which can be detected in the fractions composed of sediments of higher hydraulic values are visible also in this fraction with the exception of magnetic iron. All the iron in this fraction appears to be in the form of peroxide.

III. *Sediments* ·25^{mm} *h. v.*—8^{mm} *h. v.;* have a light chocolate color; the "streak" of the finely triturated powder is gray and approaches that of the mother-rock, being only slightly darker with a tinge of brown. The subdivisions of this fraction appear under the microscope very much alike; particles of magnetic iron are discernible in all of them and are larger with the increase of the hydraulic values.

IV. *Sediments* 8^{mm} *h. v.*—64^{mm} *h. v.;* appear grayish black, somewhat like the mother-rock, when coarsely pulverized. All constituents of the mother-rock can be discerned under the microscope in this fraction in an unchanged state.

Since it thus appears that the natural subdivisions of this soil correspond with those obtained by mechanical analysis I undertook the chemical analysis of these four fractions.

Plan of chemical analysis.—My plan was to execute a complete analysis by fusion of each of the four fractions, in order to ascertain their ultimate composition; further, to analyze the same fractions by extraction with hydrochloric acid both in their natural state and after previous trituration, in order to be able to compare them more directly, for estimating their agricultural value. The analysis of the soil itself, triturated and untriturated, by fusion and extraction, entered also into my plan of work. Lack of time, however, prevented me from executing all of these analyses; but the data which I have obtained enabled me to draw some conclusions.

Analytical methods.—The analytical methods which I have used in this comparative investigation are somewhat different

from those which it would be advisable to use if the object were to determine with the greatest possible accuracy the constituents of a rock or of a mineral. Still they are accurate enough to guarantee fair results, particularly as great pains have been taken to maintain the utmost possible uniformity of conditions.

The hydrochloric acid which was used for the extraction had the spec. grav. = 1·112. The digestions with this acid were effected in all instances on a constant water-bath for five days; 25^{cc} of acid to about $2{\cdot}5^{grm}$ of mineral powder were used. For the determination of the total phosphoric acid the finely triturated powders were digested for two and a half days on the constant water-bath with nitric acid (spec. grav. = 1·25) and the phosphoric acid in the extract after precipitation with ammonic molybdate was weighed as magnesium-pyrophosphate. For the determination of the total alkalies the method of J. Lawrence Smith was used Sulphuric acid was only determined in the hydrochloric extracts. On account of the insignificant quantities found, the determinations of this soil-ingredient were not repeated in the analyses by fusion. Only traces of manganese were found. The determination of the halogens (F, Cl) was omitted, as it had no particular value for this comparative investigation.

Extraction of the soil with cold hydrochloric acid.—It was interesting to see how the soil would be acted upon by cold hydrochloric acid. For this purpose 25 grams of the soil were digested with 250^{cc} hydrochloric acid (sp. gr. 1·112) at the ordinary temperature. It was found that the extract contained:

SiO_2	0·22	per cent.
P_2O_5	0·28	'
SO_3	0·01	"
K_2O	0·17	"
Na_2O	0·05	"
CaO	0·69	"
MgO	0·58	"
MnO	—	"
FeO	—	"
Fe_2O_3	5·61	"
Al_2O_3	2·42	"
		"
	10·03	"

In "How Crops Feed,"* Professor Johnson mentions the results of a similar experiment by Grouven on a soil of Salzmünde. Grouven found that hot diluted acid dissolved five

* Page 370.

times as much oxide of iron and alumina, as cold dilute acid, four times as much potash, three times as much soda, twice the amount of magnesia, sulphuric acid and phosphoric acid, and the same quantity of lime.

The following table shows plainly how very different the action of acids of different strength on soils can be. Hot dilute acid takes up

	From the soil of Salzmünde.	From the Rockland Ridge soil.
Al_2O_3, Fe_2O_3	5 times as much	3·7 times as much.
K_2O	4 " "	4·5 " "
Na_2O	3 " "	13 " "
MgO	2 " "	1·6 " "
SO_3	2 " "	8 " "
P_2O_5	2 " "	1·3 " "
CaO	the same amount	3·5 " "

as cold dilute acid.

I believe these two examples prove the wide range of errors, which the agricultural chemist would commit in judging as to the fertility of a soil from the composition of the extract by hot hydrochloric acid; for it is evident that if the action of hot and cold hydrochloric acid on a soil shows such wide discrepancies, the action of carbonic and other weak organic acids, which occur in the soil can hardly be compared with that of hot hydrochloric acid.

Humus determination (according to Grandeau). $10·6395^{grm}$ of the soil after extraction* with weak hydrochloric acid yielded to weak ammonia water $·1269^{grm}$=1·19 per cent of humus, which contained $·0451^{grm}$ inorganic matter=·42 per cent. The phosphoric acid in this inorganic residue amounted to 16·17 per cent of the same and to ·07 per cent calculated on the total soil.

*The soil was extracted on a filter by pouring repeatedly small quantities of the weak acid over it. 825^{cc} of a mixture containing 800^{cc} distilled water and 25^{cc} hydrochloric acid (sp. gr. = 1·112) were used. The extraction was completed in a time of about five hours. As I had already compared the action of moderately strong hot and cold acids on the soil, I thought it was worth while to ascertain the dissolving properties of a 32-times weaker cold acid on the soil. I found that the solution contained ·18 per cent P_2O_5 (extraction with HCl sp. gr. = 1·112 for five days on water-bath yielded ·28 per cent P_2O_5). Owing to an accident the determination of the bases was not completed. I can, however, state that the extract contained a considerable quantity of gelatinous silica, (zeolites).

Analyses by fusion of rock, soil and sediments.

	Mother-rock.	Fragments > 2^{mm} □ (sieve) decomposed mother-rock.	Soil.	Sediments 8^{mm} h. v.—64^{mm} h. v.	Sediments ·25^{mm} h. v.—8^{mm} h. v.	Sediments < ·25^{mm} h. v.	Clay.
SiO_2	50·85	48·42	58·16	57·07		55·94	41·52
P_2O_5*	·76	·78	·43	·33	·24	·42	·11
SO_3	·05	·03	·07	·04		not determ.	·08
H_2O	·34	1·20	1·77	·21		----	----
K_2O	1·13	1·16	1·08	1·53		1·76	----
Na_2O	2·37	2·29	2·56	2·90		1·67	----
CaO	9·33	8·98	4·57	6·55		3·07	·41
MgO	5·57	4·58	1·99	2·59		1·72	1·57
FeO	7·11	4·77	----	2·80		----	----
Fe_2O_3	10·03	10·80	10·59	8·24		11·98	17·93
Al_2O_3	12·54	16·00	15·03	17·57		16·32	17·18
Org. matter	----	----	3·52	----		7·40†	18·86†
	100·08	99·01	100·37	99·83	----	100·28	----

Discussion of the analyses by fusion of the sediments obtained by mechanical analysis.

I. *Clay:* M. Th. Schloesing, the celebrated French agricultural chemist, in speaking about "clay," says:‡ "Clay derives its origin from the decomposition of siliceous rocks. Under atmospheric influences, such as humidity, oxygen, carbonic acid, these rocks are slowly decomposed. Their alkalies and alkaline earths are transformed into carbonates. These are leached out by water; the calcium carbonate with the help of free carbonic acid; at the same time a part of the silica is set free and becomes soluble. The silicate of alumina remains intact; by taking up water it becomes clay. The iron which becomes insoluble, changing into peroxide, remains with the clay. The clay retains besides small quantities of other substances, such as alkalies and alkaline earths, in a sense as the witnesses of its origin."

It is interesting to hear another agricultural chemist upon the same subject. In the chapter on soil investigation,§ which forms a part of the "General Discussion of the Cotton production of the United States" Prof. E. W. Hilgard says: "The concentration of the available portion of the plant-food of soils in their finest portions is almost a maxim already, scarcely need-

* By extraction with HNO_3. † Organic matter and water.
‡ P. 62, Chimie Agricole. (Frémy. Encyclopédie Chimique.)
§ Tenth U. S. Census.

ing the corroboration afforded by the investigation of Dr. Loughridge."*

My own results seemed to confirm M. Schloesing's opinion, as reference to the tables containing the analyses by fusion will show; since, however, it is possible that the large quantities of water employed in mechanical analysis had leached out a considerable portion of the alkalies and alkaline earths, I prepared another portion of clay, by treating 100^{grm} of the soil with 5300^{cc} of distilled water and evaporating the resulting "clay water" to dryness.

The clay procured in this way gave the results under *a*, while the clay, which was prepared in the ordinary manner afforded these under *b*. Even if the higher figures of *a* were not partly due to the presence of the soil extract they are still lower than those obtained by analysis of the sediments 8^{mm} h. v. -64^{mm} h. v. which are given under *c*.

	a.	*b.*	*c.*
CaO	2·60 per cent.	·41 per cent.	6·55 per cent.
MgO	2·30 "	1·57 "	2·59 "
P_2O_5	·65 "	·11 "	·33 "

I give here also the analyses of *b* and *c* by extraction with hot hydrochloric acid.

	b.	*c.*
CaO	·17 per cent.	3·01 per cent.
MgO	1·16 "	1·06 "
P_2O_5	·11 "	·14 "

We see that the results obtained by extraction with hydrochloric acid are nearly proportional to those obtained by fusion.

Why is it now that Dr. Loughridge found the clay of his soil to be of all the sediments the richest in bases, while I have found the opposite? The coarser sediments of Loughridge's soil contained "nothing but quartz-sand," as that author expresses himself, while in the Rockland Ridge soil the coarser sediments are the least decomposed fragments of a rock, which is extremely rich in bases and phosphoric acid.

I have not succeeded, unfortunately, in determining the amount of alkalies in the clay, owing to the difficulty of preparing the latter in a sufficient pure state for an alkali-determination; I believe, however, that the alkalies would show a decrease, probably in the same proportion as the alkaline earths. The high percentages of alkalies which Loughridge found in the clay that he analyzed may be partly due to the solution of common salt with which the clay was precipitated. These contradicting results seem to me to indicate that the truth about

* On the distribution of soil ingredients among the sediments obtained in silt analysis by R. H. Loughridge, of Oxford, Miss. Proceed. of the Am. Assoc. for the Advanc. of Science, 1874.

the matter may be found between Schloesing's and Hilgard's views; the Mississippi soil of Loughridge and the Rockland Ridge soil which I have analyzed represent extreme types; between them numberless gradations are possible. All of the iron contained in the clay exists probably in the form of oxide. It was not possible to make a determination of iron protoxide as the amount of organic matter present was large.

II. *Silt* (*sediments* $< \cdot 25^{mm}$ *h. v.*); contains a still larger percentage of bases than the clay. It was impossible to determine the iron protoxide, owing to organic matters. A prominent feature is the high percentage of phosphoric acid. Of the coarser matters only the fraction embracing the sediments of 8^{mm} h. v.–64^{mm} h. v. has been analyzed.

III. *Sediments* 8^{mm} *h. v.*–64^{mm} *h. v.;* These sediments are the richest in bases. The amount of alkalies and alkaline earths in them approaches very nearly that of the mother-rock; the quantity of phosphoric acid, however, is only half as large as that contained in the rock. The increased percentage of silicic acid (57·07 per cent against 50·95 per cent in the rock) and the decrease of iron protoxide (2·80 per cent against 7·11 per cent) shows that a considerable chemical change has already taken place.

Analyses by extraction with hydrochloric acid of rock, soil and sediments.

	Mother-rock.	Fragments $> 2^{mm}$ □ (sieve) decomposed mother-rock.	Soil.	Sediments 8^{mm} h. v.—64^{mm} h. v.	Sediments $\cdot 25^{mm}$ h. v.—8^{mm} h. v.	Sediments $< \cdot 25^{mm}$ h. v.	Clay.
Matters insol. in HCl	65·41	66·28	71·87	80·21	83·98	66·89	42·90
SiO_2 sol. in Na_2CO_3	1·57	3·74	11·00	1·46	7·64	8·95	33·49
Matters insol. in Na_2CO_3.	63·84	62·54	60·87	78·75	76·34	57·94	9·41
P_2O_5*	0·76	0·78	0·36	0·14	0·18	0·42	0·11
SO_3	0·05	0·03	0·08	0·04	0·05	not det.	0·08
H_2O	0·34	1·20	1·77	0·21	0·34	----	----
K_2O	not†	not	·78	0·32	0·38	0·61	----
Na_2O	deter.	deter.	·67	0·91	0·63	0·52	----
CaO	6·29	6·54	2·48	3·01	2·58	2·07	0·17
MgO	3·42	3·05	·97	1·06	0·82	1·44	1·16
Fe_2O_3	13·85	14·50	9·22	3·53	4·56	10·83	17.90
Al_2O_3	8·25	10·25	8·95	10·63	5·90	9·15	15·48
Org. matter	----	---	3·52	----	----	7·40‡	18·86‡
	----	----	100·67	100·06	99·42	99·33	----

* By extraction with HNO_3. † KCl + NaCl = 4·54 per cent. ‡ Org. matter and water.

Discussion of the analyses of the sediments by extraction with hot hydrochloric acid.

These analyses have first of all revealed the fact that the amounts of alkalies and alkaline earths, which were obtained by extraction with hydrochloric acid from the sediments 8^{mm} h. v.–64^{mm} h. v., ·25^{mm} h. v.–8^{mm} h. v., $<$·25^{mm} h. v., and from the clay decrease almost proportionately to the decrease of total percentages obtained in the analyses by fusion.

The total amount of alkali-chlorides for instance in sediments 8^{mm} h. v.–64^{mm} h. v. yielded by the method of J. Lawrence Smith, is equal to 7·88 per cent. By extraction with hydrochloric acid 2·50 per cent were found. The total amount of alkali-chlorides in the silt obtained by the J. Lawrence Smith method is equal to 5·94 per cent. If we write now the proportion:

$$7{\cdot}88 : 2{\cdot}50 = 5{\cdot}94 : x$$

we find x=1·88 per cent, while 1·95 per cent of alkali-chloride were found in the silt by extraction with hydrochloric acid. The following tables exhibit these facts.

Sodium and potassium chlorides found.

h. v.	By J. Lawrence Smith Method.			By extraction with HCl.		
	Total	K_2O	Na_2O	Total	K_2O	Na_2O
8^{mm}–64^{mm}	7·88%	1·53%	2·90	2·22%	·32%	·91
·25^{mm}–8^{mm}				1·79	·38	·63
$<$·25^{mm}	5·94	1·76	1·67	1·95	·61	·52
Soil	7·48	1·08	2·56	2·50	·78	·67

Calcium oxide and magnesium oxide found.

h. v.	By fusion. Per cent.		By extraction with HCl. Per cent.	
	CaO.	MgO.	CaO.	MgO.
8^{mm}–64^{mm}	6·55	2·59	3·01	---
·25^{mm}–8^{mm}	---	---	2·58	·82
$<$·25^{mm}	3·07	1·72	2·07	1·44
Soil	4·57	1·99	2·48	·97

Phosphoric acid found.

h. v.	Total Per cent.	By extraction with HNO_3. Per cent.
8^{mm}–64^{mm}	·33	·14
·25^{mm}–8^{mm}	·24	·18
$<$·25^{mm}	·42	·42
Soil	·43	·36

It is worth while to inspect these data a little more closely.

We have found, for instance, that the soil yields to hydrochloric acid 2·50 per cent sodium and potassium chlorides (= ·78 per cent K_2O + ·67 per cent Na_2O). We have further found by mechanical analysis that the silt and the clay, those fractions from which, owing to their fineness, the plant-roots most probably derive their food, form only about one-third part of the soil (31·84 per cent). We have also seen that the other two-thirds, which consists of coarse sediments, yielded absolutely and relatively much larger quantities of alkalies to hydrochloric acid than the finer sediments. The 2·50 per cent of alkali-chlorides found in the entire soil have therefore to be divided at least by four or five in order to give us an idea of the available plant-food, which even then is very uncertain. Exactly the same reasoning can be applied to the alkaline earths.

Speaking about soils, Professor Storer says in his text-book, "Agriculture in some of its relations with chemistry," vol. i, p. 199. "With the exception perhaps of midwinter, when everything is frozen stiff, it is certain that chemical changes are constantly occurring in every soil. From the chemical point of view nothing like rest can be conceived of in a mixture so complex as the loam of an ordinary field."

Considering again the results above discussed, I should like to add that to produce a "mixture so complex" nature has to work many thousand years; it seems to me, therefore, to be a vain attempt to force an answer from a soil by a single analysis as to its fertility, which is the result of the coincidence of numerous factors, of which some, and probably many, are so occult as to escape our direct observation. Among the favorable conditions which determine the fertility of a soil must be classed,

The distribution of the phosphoric acid.

My analyses show that the sediments $<$ ·25^{mm} h. v. contain the largest amount of phosphoric acid (·42 per cent). With what bases is the phosphoric acid in the silt and in the other sediments combined?

In order to answer this question approximately I made use of the different behavior of the phosphates of iron, aluminum, and calcium toward dilute acetic acid, in which both the first-mentioned phosphates are almost insoluble and the latter soluble. The analytical results obtained by this method did not decide the question.* However, it is probable that in the

* 100 grm. silt and the same quantity of sediments ·25^{mm} h. v.–8^{mm} h. v. were treated each with 300 c.c. dilute acetic acid (25 parts glacial acetic acid to 75 parts water) for five days at ordinary temperature.

I. The silt yielded .... ·0074 grm. P_2O_5.
II. The sediments ·25^{mm} h. v.–8^{mm} h. v. yielded ... ·0043 grm. P_2O_5.

coarser portions of this soil the alkaline earth phosphates predominate, owing to undecomposed apatite, while in the finer portions which contain more of the oxides of iron and alumina they change into phosphates of iron and alumina. This supposition is confirmed by the researches of E. Peters* and Warington, Jr.†

Should we now attempt to decide about the degree of fertility of the soil, it would not be sufficient to know how much‡ phosphoric acid is contained in the soil, and with what bases it is combined; we ought also to know if the conditions in the soil are favorable to the decomposition or solution of the phosphates, particularly those of iron and alumina, so that the phosphoric acid could become available as plant-food.

Being aware of the omnipresence of the phosphates of iron and aluminum in the soil, Thenard§ has attempted to solve this question. By a laboratory experiment he showed that the available form of phosphoric acid—phosphate of calcium—is formed by a double decomposition of the phosphates of iron and aluminum and a soluble modification of calcium silicate. We must confess that even if that should be the true explanation of the phenomenon we are unable to trace those conditions in nature.

I have not made determinations of nitrogen and ammonia in the soil owing to lack of material, and other determinations have been omitted for the same reason.

The results of this investigation may be summarized as follows:

1. The action of hydrochloric acid on soils is far from uniform. This is seen when we compare the results obtained by extracting the Rockland Ridge soil with hot and cold hydrochloric acid, and the results which Grouven has published.

2. It is probable that plant-roots derive their nutrition from the finest sediments of the soil, from the clay. But this does not make necessary that the clay should be the richest of all sediments in plant-food. Such may be only the case if the coarser sediments consist of quartz-sand.

3. Hydrochloric acid corrodes powerfully not only the finest sediments of the soil, but also the coarsest. We have good

I. 100 grm. silt contain	·42 grm. P_2O_5.
II. 100 grm. sed. ·25mm h. v.–8mm h. v. contain	·24 grm. P_2O_5.

The acetic acid has therefore dissolved 1·76 per cent of the total P_2O_5 contained in the silt and 1·41 per cent of the total P_2O_5 contained in sediments ·25mm h. v.–8mm h. v. This experiment would have been probably more decisive if the sediments ·25mm h. v.–8mm h. v. had been converted by trituration to the same degree of fineness as the silt possesses.

* Annalen der Landwirthschaft, vol. xlix, p. 31.

† Journ. of the Chem. Soc., new series, vol. vi, 1868, p. 5.

‡ "A soil may contain many thousand pounds of phosphoric acid or of nitrogen and yet be in a poor condition."—R. Warington, The Chemistry of the Farm, p. 17.

§ Comptes rendus, 1858, vol. xlvi, p. 212.

reason to suppose that plant-roots derive their food only from the finest sediments with the help of carbonic and weak organic acids. Therefore, extraction with hydrochloric acid does not reproduce or represent the processes which are going on in nature.

4. The fertility of a soil greatly depends not only upon the quantity of phosphoric acid which is present, but also upon the mode of its occurrence. We are unable to ascertain with accuracy with what bases the phosphoric acid is combined in the soil; we are further utterly unable to find out if the conditions for transformation of the insoluble phosphates into soluble ones are favorable in any given soil.

5. Therefore, it is not possible to decide about the fertility of a soil on the strength of a chemical analysis. As an exception, however, I must mention certain desert-soils. If chemical analysis should reveal that such a soil consists almost entirely of silica, we can with good conscience predict to the farmer very poor harvests.

I do not profess to have brought forward any new facts. I believe to have only confirmed by my work opinions which were expressed already long ago by authorities in the domain of agricultural chemistry. As chemical soil-analysis is still carried on in America and in Europe, often, it must be acknowledged, with industry and laudable perseverance, I thought it to be my duty to communicate my results, however modest and fragmentary they may be, to my fellow workers, with the hope to prove myself useful to them.

1887. Berkeley, Cal.

Art. XXV.—*On the Rosetown Extension of the Cortlandt Series*; by J. F. Kemp.

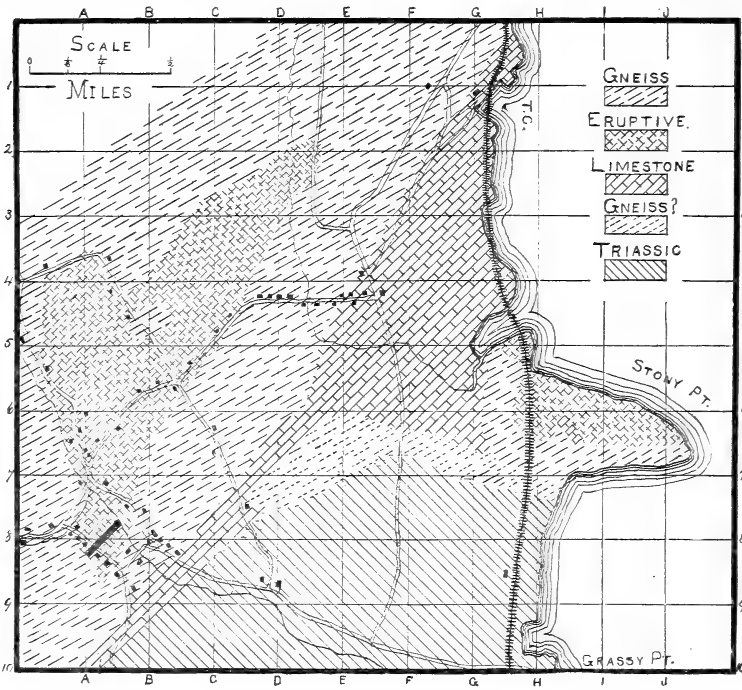
In the fieldwork of the New Jersey Survey of 1885,* Dr. N. L. Britton and Mr. F. J. H. Merrill came upon evidences of what appeared to be a further extension of the well known Cortlandt series† on the Hudson River. They were due west of Stony Point, about the small cross-roads settlement known as Rosetown. The observations were suggested to the writer and by him the following results have been worked out so that the Rosetown area is now definitely circumscribed.

As will be seen from the accompanying map it extends in an irregular shoe-shaped outline with its longer axis running ap-

* Ann. Rep. N. J. State, Geol. 1886, p. 70; School of Mines Quarterly, vol. ix, p. 33.

† This Journal, III, xx, p. 194.

proximately N. 40. E. It covers about three-quarters of a square mile and is surrounded on all sides by the gneissic rocks of what Dr. Britton has called the Iron-bearing Group. At the southwest it encloses a bed of limestone now changed to a compact crystalline marble, which shows, as will be noticed further on, peculiar evidences of contact metamorphism. Around the edge of the eruptive area the gneiss is fissured by small dikes, and itself bears witness of having been subjected to some powerful action. It breaks in small angular lumps, loses its bedding or lamination, and under the microscope ex-



hibits the large normal crystals of orthoclase broken into innumerable smaller masses which polarize as individuals. Between the Stony Point area of the original Cortlandt Series and the nearest outcrop of the Rosetown area about one mile intervenes. This is made up of a narrow band of much contorted schist in the immediate vicinity of Stony Point, of the Tompkins Cove blue limestone and the Archæan gneiss. On the south, the Triassic conglomerate and shales* form the surface but in no place do they come in contact with the eruptives and their dip and strike are widely different from the limestone. In C, 9 and

* Russell, I. H., Annals N. Y. Acad. Sci., vol. i, (1878), p. 237.

D, 8 the limestone outcrop cannot be traced because of the drift, and is inferentially filled in. In C, 9, and B, 10 it is however, represented by a hard, flinty, stratified rock, which doubtless corresponds to the slaty layers exposed at Tompkins Cove. It is however very badly contorted and broken. Topographically, the country consists in general of high hills or ridges of gneiss, surrounding a valley which is filled by the eruptives. These latter afford low hillocks and rolling ground of a character peculiar to themselves.

The massive rocks are in almost all cases, aggregates of hornblende, biotite and plagioclase, with abundant magnetite, and are therefore diorites. Augite is frequent, and the common accessory included minerals are as usual present. They differ from the original Cortlandt in showing, so far as the writer's observation has gone, no hypersthene, nor, although there are individuals whose external appearance strongly resembles the peridotites and pikrites of Croton Pt., have I been able to identify any olivine in the slides.

The simplest type (No. 76, from C, 6), exhibits hornblende, plagioclase and magnetite with occasional biotite. The hornblende is of both brown and green kinds. The former is in large, irregular masses 5 to 20 × 50 to 200 ^{mm}., strongly pleochroic, *c*, dark brown; *b*, the same; *a*, yellow. The green variety is feebly pleochroic, of fibrous or acicular character and may be derived from the brown. The brown variety alters to chlorite with secondary magnetite. The plagioclase is also in large irregular masses well twinned. A sample isolated by Thoulet's solution (spec. 69) afforded analysis I.

	I.	II.
SiO_2	61·12	49·30
Al_2O_3	23·90	22·46
Fe_2O_3		12·04
CaO	5·80	9·30
MgO		2·14
K_2O	2·58	1·27
Na_2O	6·78	3·01
Loss on ignition	----	·78
	100·18	100·30

This shows it to be a nearly typical oligoclase whose soda has been in part replaced by potash. The magnetite is in large irregular grains and as small secondary products from the hornblende. Apatite is not infrequent. An analysis of the rock (spec. 76) gave the results in analysis II above. Three determinations of the specific gravity gave 3 003, 3·015, 3·025.

Starting from this as a normal type, the simplest deviation consists in the increase of biotite and relative decrease of horn-

blende, which may go so far that (as in 102 from A, 7) no hornblende remains and the rock is a pure mica-diorite.

In the less simple mineralogical aggregates augite frequently appears and at times in considerable amount, forming as much of the rock as any other component. It is light, transparent green in color, not at all pleochroic and exhibits well marked cleavage and characteristic optical properties. Some large detached masses (in B, 8) evidently not far from place, were found to consist almost wholly of brown hornblende and green augite, a very curious and interesting mixture. (Spec. 207.) The hornblende is in large irregular masses perhaps 10mm. × 15mm. of rude, corroded prismatic outline. These are surrounded by smaller, often idiomorphic crystals of augite and frequently contain abundant masses of the same scattered throughout. This association suggested the interesting question of the paramorphosis of these two minerals.* As the most reliable basis from which to draw any inference, enough of each mineral was isolated by careful sorting for analysis.

	III.	IV.	V.
SiO_2	43·60	46·00	43·35
Fe_2O_3	14·08	11·20	5·61
Al_2O_3	20·02	14·80	29·75
CaO	12·19	15·52	12·46
MgO	4·03	4·75	2·03
K_2O	2·06	4·70	5·93
Na_2O	3·50	3·20	tr.
Loss on ignition.	----	----	0·73
	99·48	100·17	99·86

(Numbers III and IV are the hornblende and augite, respectively, analyzed by the writer. No. V is an analysis of a somewhat altered piece of the same rock kindly made by Mr. L. M. Dennis, instructor in chemistry in this university.)

These analyses show that the hornblende is more basic than the augite and corroborate the view first taken from the slide, that the augite has been formed subsequent to the hornblende by the corroding action of the more acid magma which remained after its differentiation. A similar process with the formation of magnetite has been described by Oebbeke in the andesites of the Phillipines;† but elsewhere in the older rocks‡ and especially in those of the main Cortlandt,§ the process of change in these minerals seems to have occurred in the

* G. H. Williams, this Journal, III, vol. xxviii, p. 259. Full references and a review of the literature are here given.

† Neues Jahrbuch, Beil. Band i, 1881, p. 474.

‡ Rosenbusch, Mikros. Phys., Band i, p. 468.

§ G. H. Williams, this Journal, vol. xxxi, p. 33, Jan., 1886.

reverse succession. The succession here noted is also in accord with artificial experiment.

Between the general diorite that forms the greater part of the Rosetown area and the diorites and mica-diorites of the main area, the writer can trace no mineralogical differences worthy of note except those already given. Omitting the hypersthene and olivine from consideration it would doubtless be possible to find types corresponding with those described by Dr. Williams, but it would simplify matters in no respect. The writer would express his obligations to Dr. Williams for the kind loan of a series of typical sections from the main Cortlandt with which to compare his results. As mineralogical aggregates they are quite analogous.

Around the edges of the area, where the massive rocks come in contact with the gneiss, numerous small dikes have been developed. They vary from one to several inches in width and consist very uniformly of brown and green hornblende, $0{\cdot}1^{mm}$ to $0{\cdot}3^{mm}$ intermingled with feldspar masses no larger. The hornblende crystals tend to have their longer axes arranged parallel with the walls of the dike. The feldspar rarely shows twinning and its composition must generally be inferred from the analysis. The feldspar is however filled with inclusions of hornblende, rutile, and less often apatite. The following analysis (spec. 66a) kindly made by Mr. L. M. Dennis, shows the notably high percentage of TiO_2, which would be inferred from the slide.

	VI.
SiO_2	49·93
FeO*	2·74
Al_2O_3	24·64
CaO	6·265
MgO	2·426
TiO_2	6·007
Na_2O	2·204
K_2O	3·797
Loss on ignition	1·2
	99·209

The structure of most of these dikes is quite uniformly allotriomorphic and in the majority of cases no amorphous matter or distinct magma can be noted (exception mentioned later). The hornblende has generally crystallized first after the oxides but at least one instance (slide 68) has been remarked in which a plagioclase is included in hornblende. Along the border of one small offshoot (66a) which is 4^{mm} broad the microscope shows a selvage of fine quartz and feld-

* All of the iron estimated as FeO.

spar crystals 0·1^{mm} to 0·3^{mm}, evidently produced from the large quartz and feldspar of the gneiss by contact. In polarized light this resembles a beautiful fine mosaic (kataklasstructur ?) apparently protecting the gneiss from the further metamorphosing action of the dike. These contact phenomena are to be seen very generally around the area but the best exposure is perhaps in the roadside in D, 5 and C, 6. On the roadside in A, 6 where the area trends to the north at the site of a supposed silver mine is a dike which proves to be a hornblende porphyrite which is interesting as exhibiting a different facies from the other contact dikes, and one more of the character that would on a priori grounds be expected. It seems reasonable to infer that this latter was intruded between walls possessing less heat for some reason than those of the former, and was thus more suddenly chilled.

From somewhere near this same locality a piece of so-called iron ore was given me by a farmer, but the exact point was kept secret. It appears on section to be a hard and very compact mixture of magnetite and emery or corundum and to be thus a similar occurrence to those in the main Cortlandt.*

In the bed of the brook below the M. E. parsonage (B, 8) is another most peculiar contact mass. The rock is of porphyritic character very similar to the curious porphyritic rocks occurring near Montrose. It contains, however, all manner of included masses of gneiss and limestone, resembling a pudding into which the enclosed masses have been stirred. In macroscopic characters the enclosed limestone resembles very closely the mass on the summit of Stony Pt. Under the microscope it is seen to be an exceedingly finely crystalline aggregate of calcite crystals $\frac{1}{10}^{mm}$ in diameter mingled with some, more brightly polarizing but undetermined mineral in crystals no larger. Scattered grains of pyrite are also to be seen.

Back of the lime-kiln in B, 8 and 9 is found the mass of included marble above referred to. This is colored dead black on the map. As much as thirty feet in thickness have been exposed by the quarrying, but the exact contact with the diorites is not shown. They however are found but a short distance north and south, proving it to be an included mass. In general the limestone is a beautiful white crystalline marble, in places very curiously banded. There are, however, numerous masses along its outer edges which are shown by the sections to consist quite entirely of tremolite. The limestone also exhibits the half fused appearance of similar contact masses the world over. A similar limestone or marble is said by the farmers to have been found in the bed of the brook near the porphyritic

* J. D. Dana. This Jour., III, xx, p. 199--200.—G. H. Williams, ibid., xxxiii, p. 194.

rock above referred to, but I was unable to find it myself. If so, it probably furnished the included masses there mentioned.

Along the roadside in B and C, 5, a mass of included gneiss is to be seen. This is very firmly crystalline, appearing almost massive in character, and is more compact and hard than the neighboring gneiss in place. It is said that stone for bridge-piers and culverts was obtained here by the West Shore Railway engineers on account of its strength.

While this area is far smaller than the original Cortlandt, it yet is large enough to exhibit in its mass very perfectly the coarse, holocrystalline structure, characteristic of plutonic masses, shading off toward the contact into finely crystalline or porphyritic types. Moreover, as the general axes of both this area and the main Cortlandt run approximately parallel to the strike of the gneiss and limestone the inference is suggested that they welled forth from longitudinal fissures produced by the general folding. Also that the Rosetown mass broke across and through the intervening beds of limestone and gneiss and formed the westerly extension and that in its passage it took up the masses of limestone and gneiss now found included. From the undisturbed condition and unconformable strike of the neighboring Triassic beds it is safe to infer that the outbreak was previous to the Trias. It is clearly subsequent to the Tompkins Cove limestone. If this is Cambrian as seems increasingly probable the intrusion of the Cortlandt series certainly occurred in the Palæozoic.* We would infer, however, from its general holocrystalline character that the mass, as now seen, solidified a considerable distance beneath the surface and under great pressure and slow cooling.

The credit of the discovery of this area belongs to Dr. N. L. Britton, and the writer is indebted to him for the suggestion of its elaboration. It is not improbable that other outlying masses may be found in further field work in the Highlands. In the rear of the Tompkins Cove School numerous stray pieces of feldspar porphyry, like the rock near Montrose Station have been found by the writer quite disconnected with either area. In the foot of the Dunderberg the West Shore R. R. cuts show numerous dikes which seem to be closely related. From this same region Mather† mentions under the name greenstone not a few localities of probably intrusive rock, but his descriptions are too unsystematic to serve as other than suggestions for subsequent workers.

Geological Laboratory, Cornell University, Ithaca, N. Y.

* J. D. Dana. This Jour., III, vol. xxviii, p. 386.

† N. Y. State Survey, Geol., 1st Dist., p. 539 and elsewhere.

ART. XXVI.—*The Contact-Metamorphism produced in the adjoining Mica schists and Limestones by the Massive Rocks of the "Cortlandt Series," near Peekskill, N. Y.;* by GEORGE H. WILLIAMS. With Plate VI.

IN three former papers I have described the principal types and some of the intermediate varieties forming the complicated group of massive rocks known as the "Cortlandt Series."* Aside from their own intrinsic interest, these rocks are hardly less worthy of attention on account of the unusual contact-metamorphism which they have occasioned in the adjoining schists.

The area occupied by the Cortlandt massive rocks—about twenty-five square miles in extent—is bordered on the south mainly by mica schists and on the west mainly by limestones. Both of these rocks have been altered by the masses which have broken through them, although the metamorphosing influence has not extended far from the contact. The gneisses, on the other hand, which border the Cortlandt area on the north, do not appear to have been materially affected.

The two localities where these phases of metamorphism were best observed—both already known through Professor Dana's descriptions of them—are here selected as typical. A further search would doubtless reveal other localities as interesting, while the emery and iron (pleonaste) deposits already described by the writer as occurring in the southern part of the Cortlandt area,† may with certainty be referred to the same category.

The two typical localities referred to are: for mica schist metamorphism, Cruger's Station; for limestone metamorphism, southern end of Verplanck Point.

I. *Contact-metamorphism in the Mica Schist.*

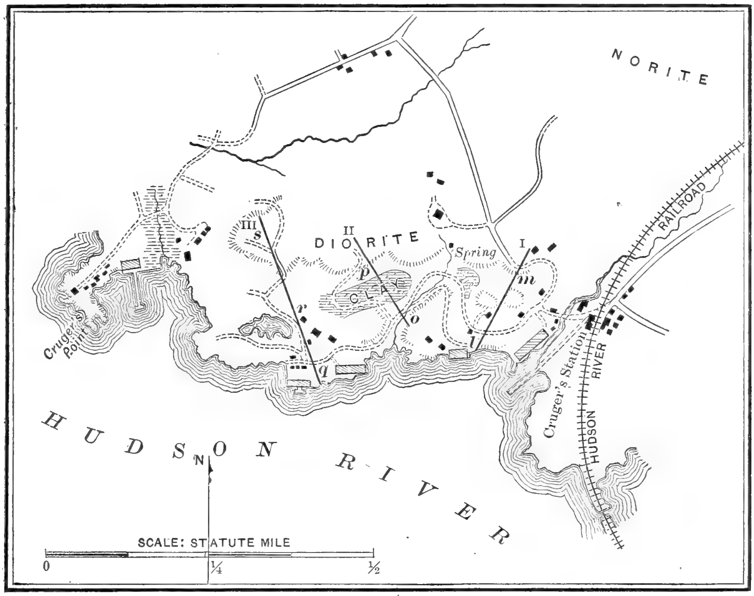
If we leave the train at Cruger's, a station on the Hudson River Railroad about four miles south of Peekskill, we find ourselves near the river-bank which at this point extends nearly west for about three fourths of a mile. Near the shore the rocks exposed are mica schists, but these are frequently covered by beds of clay which is used in the numerous brick-sheds of this region. Not over a few hundred yards from the shore rises a rocky wall which extends nearly parallel to the river bank until this bends toward the north. This wall coincides with the southern edge of the massive rocks of the "Cortlandt

* This Journal, III, xxxi, p. 26, Jan., 1886; ib., xxxiii, pp. 135 and 191, Feb. and March, 1887; ib., xxxv, p. 438, June, 1888.

† This Journal, III, xxxiii, p. 194, March, 1887.

Series," which here consist of mica-diorite or mica-hornblende-diorite. No exposure could display more favorably than this one the contact-phenomena between the massive rock and adjacent schists.

This small area is represented on Professor Dana's map,* but it is here reproduced on a much larger scale from the manuscript chart in the office of the U. S. Coast and Geodetic Survey in Washington. The particular points designated by let-



Map of the region near Cruger's Station.

ters are the same as those used by Professor Dana.* They represent three different sections across the schists, one 300–400 yards (*l-m*); one 700 yards (*o-p*); and are 900 yards (*q-s*) west of Cruger's Station, and are as good as any that could be selected.

The mica schists of this area adjoin conformably the small limestone area at Cruger's Station and have an average strike N. 70° E. and dip 75° N.; i. e. they strike nearly parallel to the river bank and dip toward the massive rocks. On the shore they are highly crystalline, but not much crumpled or metamorphosed. As we follow them, however, across the strike they become more and more puckered and filled with lenses or eyes of quartz containing garnet and other contact minerals. In the schists themselves are developed staurolite, sillimanite, cyanite and garnet. The intensity of the metamorphic changes is directly proportional to the nearness of the

* This Journal, III, xx, p. 195, Sept., 1880.

schist to the massive rocks. Just at the contact the schistose structure almost wholly disappears and the rock becomes hard and massive.

In order to understand these interesting alterations more perfectly, we will examine each of the three above-mentioned sections somewhat in detail.

Section I.—At a point on the river shore just west of the first brick-yard (*l* on the map) mica schist is exposed at the water's edge This stands nearly vertical and is finely banded and very schistose, but is hardly at all crumpled or even bent. A thin section, cut parallel to the bedding (No. 21), shows it to be composed of quartz, biotite, muscovite and feldspar, (both orthoclase and plagioclase) although the last-named mineral is comparatively rare. Tourmaline in well-formed crystals is common and zircon is also quite abundant, often occasioning the pleochroic aureoles in the biotite (Pl. VI, fig. 1).

Not far from here, limestone is exposed and some of this schist is so impregnated with calcium carbonate as to be over half calcite. A specimen of this (No. 22) shows under the microscope mainly quartz grains with some mica, both biotite and muscovite. The quartz is filled with black granules and contains an astonishing amount of rutile. This latter mineral occurs in sharp crystals, mostly twinned, which range from those thick enough to show a deep yellow color down to the minutest which the microscope can reveal.

No. 23 of the University, and K in Professor Dana's collection were obtained from a short distance north of those last described. They are somewhat more contorted and contain more abundant quartz nodules, but do not differ materially from the less-altered mica schists except in the fact that garnet has been quite abundantly developed in them. The quartz, both kinds of mica and the feldspar remain, but no tourmaline was observed. No. 24, from a point somewhere farther north, is a contorted muscovite-biotite-schist containing many quartz "eyes" together with an abundance of large dodecahedral red garnets.

A slide in Professor Dana's collection marked M and made from a specimen obtained on the line of section I, not far north of the brick-sheds, is of remarkable beauty. It represents the first phase of sillimanite-formation, where this mineral has room for its complete development (Pl. VI, fig. 2). The base of this rock seems to be quartz, triclinic feldspar and biotite. The first constituent is filled with the minute, hair-like microliths, which have been so often described but never yet determined. The biotite contains magnetite and an occasional zircon. The new products are sillimanite, garnet and rutile. The sillimanite forms thick brownish individuals which break

up into radiating tufts at the extremities. They are arranged in every direction and penetrate equally all of the other constituents. Some of these tufts resemble in their appearance the radiating tourmaline in the well-known Luxullianite. The microscopic structure of the fibers is in all respects characteristic.* They vary from those of considerable thickness to microscopic hairs. The garnet presents no unusual features. The rutile forms often large but sharply defined crystals of a deep red color.

At a point ten yards from the contact (*m* on the map) on the line of section I, the schist is very much contorted, although still well bedded (No. 14). The microscope shows that the quartz and feldspar have been reduced to a minimum; while sillimanite, mica and garnet compose most of its substance. The sillimanite is arranged in radiating tufts made up of needles so minute that their crowded aggregation is hardly transparent even in the thinnest sections. Around the edge of these masses, however, where the delicate fibers project into the surrounding quartz or biotite, the characteristic structure of the sillimanite is at once apparent. The grayish tufts are so abundant as to compose a large proportion of the rock. Between them is a rich brown biotite, frequent large flakes of muscovite, garnet grains and crystals, and some quartz. Feldspar is rare, but opaque black grains of magnetite are thickly scattered through the mica. This aggregation produces a striking contact rock, but one which is quite constant along the whole extent of the Cruger's area. It is frequently modified by the presence of staurolite, as we shall see beyond.

Directly at the contact between the schists and massive rocks, at a point in the wall marked *m* on the map (Section I), the bedded rock appears to be more or less fused with the mica-diorite, which here itself becomes very garnetiferous. Even where the bedding of the original schist is still distinct, a great variety of mineral aggregates may be obtained. No. 18^{b} is essentially a mixture of staurolite, garnet and biotite, containing considerable quartz and feldspar. In this particular specimen there is very little sillimanite. No. 16, from this same exposure, shows the actual contact with the diorite in the hand specimen. The schist is here changed to an almost colorless pyroxene, with some dark green hornblende and a little quartz.

No. 18^{d}, a dark greenish rock from this same contact, proves, upon microscopical examination, to be of unusual interest. It contains a green diallage, in which both pinacoidal partings are well developed. This is pleochroic as follows: $\mathfrak{c}=\mathfrak{b}$, bluish green; $\mathfrak{a}$=yellow. This mineral occurs in rounded grains and

* cf. Kalkowsky: Die Gneissformation des Eulengebirges, Leipzig, 1878, p. 5, *et seq.*, Pl. I, figs. 1–4.

has a high angle of extinction. In different parts of the thin sections, however, it is associated with different minerals. In one place it occurs with a triclinic feldspar, like that characteristic of the adjoining diorite; in another it is associated with muscovite, and in a third with a colorless granular mineral, whose optical properties show it to be scapolite. Its grains show sometimes parallel, sometimes rectangular cleavage lines; its refractive index is low, but its interference colors (double refraction) very brilliant. Sections showing the rectangular cleavage are isotropic or nearly so and exhibit in convergent polarized light a negative uniaxial figure. The substance agrees perfectly in its appearance and optical behavior with the scapolite described by Michel-Lévy in the "*gefleckter Gabbro*" from Bamle in Norway.* Sphene, often associated with ilmenite, is also common in this rock.

Section II (*o–p* on the map), shows essentially the same series of changes as those described under Section I. No. 25, from the schist exposed at *o*, on the opposite side of the claybank from the wall *p*, is the same mica schist as occurs at *l* (Section I), with sillimanite and staurolite abundantly developed in it. (Pl. VI, fig. 3.) The quartz, biotite and muscovite are like those described in No. 21. The tourmaline, however, seems to be lacking in this section and the feldspar is rare. The sillimanite occurs in the gray radiating tufts as described inNo. 14; but the most abundant constituent of all is the staurolite. This occurs in rather large and stout, more or less perfectly rectangular sections, which possess a high index of refraction. They show no well-developed cleavage, but have an irregular cross-parting. The pleochroism is very marked, being parallel ć, orange; parallel ă and b̄, pale yellow. The staurolite individuals are often filled with inclusions of quartz and magnetite.

As we pass across the strike of the schists from *o* toward *p* the contact (section II), the quartz steadily diminishes in quantity, and biotite and sillimanite are proportionately increased. Indeed, the mica schist finally becomes almost wholly a mixture of these two minerals, with a little garnet and magnetite.

No. 36, collected a short distance north of No. 25, is largely composed of brown biotite and gray tufted sillimanite, although considerable quartz, muscovite and staurolite still remain. Garnets and occasional small zircons are also present in this specimen. No. 37, however, from a point still nearer the contact, has lost almost every trace of the quartz, muscovite and feldspar of the original schist. The staurolite too has almost disappeared. Garnet, on the other hand, is largely de

* Bull. Soc. Min. de France, i, 43, 1878.

veloped, its crystals being penetrated by the biotite and sillimanite which compose most of the remainder of this rock. Another mineral, noted in this specimen for the first time, is cyanite. This occurs in thick, colorless crystals, with the prismatic planes well developed, but without terminal faces. The cleavage is marked by fine sharp lines parallel to the prism, and the parting parallel 0P, due to gliding, as shown by Bauer,* is also very distinct. (See Pl. VI, fig. 4.) The extinction is in all sections greatly inclined.

Specimen No. 27 shows the actual contact of the schist and the diorite. Even the thin section is composed half of diorite and half of the schist, which has here become, as in the case of rocks similarly situated at *m*, an aggregate of quartz, feldspar, colorless pyroxene and garnet (cf. Nos. 16 and 18[d]). Epidote, zoisite and calcite also occur in this section.

A study of the sections above described shows that there is an undoubted metamorphism in the mica schist, which increases regularly as the massive rocks are approached. This metamorphism consists of an addition of alumina and iron and the corresponding decrease in the proportions of silica and the alkalies. This is shown by the disappearance of the quartz and muscovite and the development of biotite, sillimanite, staurolite, cyanite and garnet.

The four following analyses, which were kindly made at my request by Mr. Frank L. Nason of the Troy Polytechnic Institute, clearly indicate the nature of the chemical changes which the schists have undergone.

	I.	II.	III.	IV.
SiO_2	62·980	61·570	55·120	40·160
Al_2O_3	16·881	19·529	24·320	29·500
Fe_2O_3	2·479	5·443	6·130	19·660
FeO	5·000	2·608	4·990	5·800
CaO	trace	trace	trace	trace
MgO	1·580	1·900	trace	0·850
Na_2O	3·020	3·480	2·712	1·460
K_2O	7·450	2·140	2·826	1·360
TiO_2	-----	1·530	2·460	-----
S	0·080	0·846	1·230	0·820
P	trace	trace	trace	trace
Total,	99·470	99·046	99·788	99·610

* Zeitschrift der deutschen geologischen Gesellschaft, xxx, p. 283, 1878.

I. No. 21. The least altered mica schist from the southern end of Section I. Contains quartz, orthoclase, biotite, muscovite; a little oligoclase, tourmaline and zircon.

II. No. 24. A much crumpled, garnetiferous mica schist, collected north of the road on Section I.

III. No. 25. Schist from *o* on Section II. Contains biotite, muscovite, quartz, sillimanite, garnet and very much staurolite.

IV. No. 37. Schist at the foot of the contact-wall, *p*. Section II. Composed of biotite, magnetite, sillimanite, cyanite and garnet.

It is not intended to imply that the successive layers of the schist may not have differed very materially in their original composition. That such was the case is shown by local variation in the relative proportions of the resultant minerals; but after allowing for all such differences, there is still a regular and progressive series of changes in the order above indicated.

Section III.—(*q-s* on the map.) This section is like the others in showing a gradual and constantly increasing metamorphism of the mica schist as we pass from the river bank at *q*, up the road which winds along the hill about half a mile west of the railroad station. Its main interest, however, is derived from the inclusions of the schist within the massive rock itself. These inclusions differ very much in size and character but they exhibit the extremest place of the metamorphic action. The largest inclusions are, as might be expected, nearest to the contact. Here some bands may be traced for a hundred feet or more, as though the molten rock had been forced between the schist strata without greatly displacing them. Farther within the contact line, on the top of the hill above Cruger's Point, many smaller inclusions of various shapes and sizes may be seen. They have been quite fully described by Professor Dana, at least so far as their macroscopic appearance goes.*

These included schist fragments are of great petrographical interest because of the variety of unusual mineral aggregates which they present. That these minerals are very largely new crystallizations produced by metamorphic action, is in some cases shown by their having an arrangement parallel to the boundaries of the fragment. The accompanying figure represents the banding in an inclusion about five feet long exposed on a glaciated surface of the mica-dorite, just where the road reaches the top of the hill. Toward the right the banding plainly follows the outline of the inclusion. Specimens No. 30 and 31 were taken from this inclusion.

Ascending the line of this section we came first (*r* on the map) to the exposure of highly contorted schist figured by Professor Dana.† A thin section of this (No. 5), cut across

* This Journal, III, xx, pp. 209–210, Sept. 1880. † Loc. cit. p. 209, fig. 11.

the grain, shows layers of varying composition, all however filled with metamorphic minerals. The original character of the mica schist with muscovite, biotite and a little tourmaline (cf. No. 21) is still well preserved, but the grain in the different layers differs very much, and in some garnet, and in others staurolite has been largely developed.

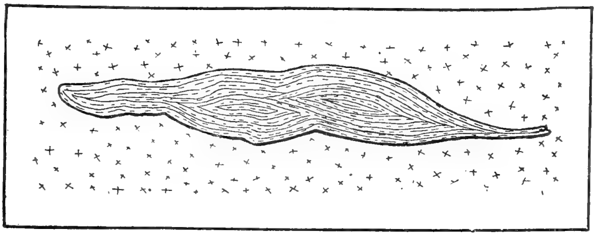


Fig. 1. Inclusion of schist in mica-diorite showing concentric arrangement of minerals. Length about five feet.

A short distance beyond this point the schists give place to the massive mica-diorite, when the inclusions become the object of special interest. These show such a manifold variety that hardly any two thin sections possess exactly the same mineral composition; still all the specimens collected fall naturally into four groups according to the nature of their prevailing constituents. These groups are as follows:

Group 1. Black inclusions consisting mostly of pleonaste and corundum.

Group 2. Inclusions consisting mostly of quartz grains.

Group 3. Inclusions consisting mostly of staurolite and green mica.

Group 4. Inclusions consisting mostly of margarite.

Group 1. The first inclusions encountered in following the road up the hill side are the small black ones disseminated through the mica-diorite. They are often arranged in rows more or less sinuous, as figured in Professor Dana's paper.* These are represented by Nos. 7, 7[a] and 29 in the University collection, and by W and Cr. 7 in Professor Dana's. The microscope shows them to be composed mainly of pleonaste in octahedral crystals. With this is associated some magnetite, biotite and feldspar. In the densest of the pleonaste inclusions, colorless corundum is very abundant. This is notably the case in No. 29, where this mineral forms comparatively large and well-developed crystals. (Pl. VI, fig. 5.)

These isolated inclusions of spinel and corundum are almost identical with the more extensive deposits of the same character occurring near the southern border of the norite region

*Loc. cit., fig. 12.

farther to the east, and described at length in a former paper.* Their origin in both cases is without doubt essentially the same.

Group 2. Certain of the included masses in the diorite higher up the hill are composed mainly of quartz. Nos. 10, 30 and 31 represent this class. The quartz grains contain the well-known black, hair-like needles in greater perfection than any which have ever come under my notice. These are often arranged zonally forming a matted net-work, as it were, around the principal axis of the quartz crystal, while the interior and periphery are quite free from them. Many other accessory minerals were observed in these quartz inclusions. These vary very much in their amount and relative proportions. Those noticed were magnetite, pleonaste. zircon, apatite, sphene, garnet, tourmaline, muscovite, green mica, biotite, hornblende and plagioclase.

Group 3 of the inclusions in the diorite are principally made up of staurolite and a green mica, associated with a greater or less amount of sillimanite. Representatives of this class are found in sections Nos. 9 and 11 of the University collection, and among those belonging to Professor Dana, those marked EW, EW 1 and Cr. 8. The staurolite and sillimanite possess the same characteristics which have already been described in connection with the altered mica schists. The bright green, micaceous mineral is a member of the chlorite group, as is shown by its chemical behavior; while an optical examination serves to more specifically identify it as *ripidolite* or *clinochlore.* In prismatic sections it shows a decided pleochroism :—O = green, E = light yellowish green; absorption O > E. Both its refractive index and its double refraction are very weak. Basal cleavage sections in converged polarized light show a positive interference figure with a small optical angle. The monoclinic character is apparent from the bisectrix not standing quite normal to the basal pinacoid. Cleavage flakes of a typical ripidolite specimen from Westchester, Pa., examined for comparison, yielded exactly similar results.

There is no doubt that this green mica has been derived from a brown biotite, for many incompletely changed crystals show a gradual transition from the one mineral to the other. The specific gravity of the green mica (2·9), which is exceptionally high for clinochlore, is probably due to the fact that it is still associated with more or less biotite. Accessory minerals observed in the thin sections of the inclusions belonging to Group 3 are garnet, tourmaline, corundum, quartz, feldspar,

* This Journal, III, xxxiii, p. 194, March, 1887.

biotite, magnetite, and margarite, which latter mineral will be particularly described under the next group.

Group 4 comprises inclusions which are largely composed of a micaceous mineral, bearing a close resemblance to muscovite. It forms a confused aggregate of flakes with no regularity in their arrangement, and is associated with varying amounts of green mica, tourmaline, magnetite, epidote, staurolite, etc. Specimen No. 32, taken from an inclusion in the mica-diorite near the head of the road leading up the hill at Cruger's Point (*s* on the map), is almost wholly composed of this mineral. Macroscopically it bears every evidence of being muscovite, but a careful examination shows that it possesses several characteristics which are foreign to this species.

Under the microscope the lath-shaped cross-sections at once appear different from muscovite by their high refractive index, which throws their boundaries and cleavage lines into high relief. Moreover they show between crossed nicols a distinctly inclined extinction, varying, when measured against the cleavage, from 6° to 10°. There is also a very frequent twinning parallel to the basal pinacoid. The interference colors in polarized light are as brilliant as those of muscovite, but the optical angle is far too large for that species. Measured in the air it gave a value of $114\frac{1}{2}°$, while the limit for muscovite is 70°. The asymmetric position of the interference figure when examined in a cleavage flake also indicates that the bisectrix is considerably oblique to a normal to the basal plane. The character of the double refraction is, as in the case of muscovite, negative.

The optical properties here enumerated are seen to be intermediate between those of muscovite and the brittle micas or chloritoids. The same thing is true of the hardness (3·5–4) and specific gravity (3·1) of the mineral here under consideration. All of these physical characters, however, agree accurately with those given by Des Cloizeaux* and Tschermak† for the lime mica, margarite, (=Perlglimmer *Germ.*, Emerylite *Smith*), which is well known to occupy a position between true mica and chloritoid. This conclusion is fully substantiated by the following analysis (I), made by Mr. T. M. Chatard, of the U. S. Geological Survey at Washington. The rather small amount of material for this analysis (0·4212 gr.), was obtained from specimen No. 32 by as complete a separation as possible with the Thoulet solution. A very small proportion of black tourmaline still remained with the powder analyzed, which may in a measure account for the rather high percentage of iron.

* Manuel de Minéralogie, i, p. 501, 1862.

† Die Glimmergruppe: Zeitschr. für Krystallogr., ii, p. 48, 1877.

Owing to the small amount of material the alkalies were not determined:

	(I.)	(II.)
SiO_2	32·73	32·21
Al_2O_3	46·58	48·87
FeO	5·12	2·50
CaO	11·04	10·02
MgO	1·00	0·32
Na_2O	----	1·91
Li_2O	----	0·32
H_2O	4·49	4·61
	100·96	100·76

Under (II) is given for comparison an analysis of the margarite from Chester, Mass., made by the late Professor Lawrence Smith.*

The occurrence of margarite as a contact-mineral in the Cortlandt schist inclusions is interesting in connection with the occurrence under the same circumstances of corundum, with which margarite is always associated.

The amount of margarite in the schist inclusions varies very much in different specimens. In some cases it forms a large proportion of the entire mass, while in others it is associated with a greater or less amount of the other contact-minerals. In this manner the inclusions classed in this group grade insensibly into those of the other groups, although it is a noteworthy fact that the margarite was not observed in those particular inclusions in which corundum crystals were most abundant. The microscopic appearance of the margarite is shown in Plate VI, figure 6.

In many of its features the Cortlandt area is quite unique and yet it finds many close analogies in certain regions which have recently been made the subject of detailed petrographical study in Europe. The region which seems most closely to resemble the Cortlandt area is that so admirably described by Teller and von John, near Klausen in the Tyrol.† Here occurs a large eruptive mass exhibiting many facies and closely resembling the Cortlandt eruptives save in the absence of hornblendic and peridotitic types. The authors distinguish: Norite, Quartz-norite, Norite-porphyrite and Quartz-mica-diorite. In many instances also a monoclinic pyroxene is associated with the hypersthene and enstatite. The close resemblance of the Klausen to the Cortlandt area is furthermore increased by the contact-phenomena produced in the adjacent schists. These,

* This Journal, II, xlii, 1886. Original Researches, 1884, p. 120.

† Geologisch-petrographische Beiträge zur Kenntniss der dioritischen Gesteine von Klausen in Südtirol. Jahrb. der k. k. geol. Reichsanstalt, xxxii, 1882, pp. 589–684.

both as regards actual contact and inclusions, are much alike at the two localities—a fact that has already been noted by Professor Rosenbusch.*

Contact-phenomena have been so rarely studied in the crystalline schists that mention should also be made in this connection of the unusual mineral aggregates which were first observed by Professor Lossen in the kersantite of Michaelstein in the Harz Mountains.† These have recently been carefully studied by Dr. Max Koch of Berlin,‡ who suggests, as the most probable explanation of their anomalous character, that they are metamorphosed inclusions of crystalline schists. There are important individual differences between the Michaelstein and Cortlandt inclusions, but yet there is sufficient resemblance both in structure, mode of occurrence and mineral composition, to make it certain that the two belong to the same general category.§

For the sake of comparison a list of the metamorphic minerals (exclusive of quartz, feldspar and biotite, which are common to all), which have been observed at the three above named localities is here appended:

Cruger's.	Michaelstein.	Klausen.
Sillimanite,	sillimanite,	———
cyanite,	cyanite,	———
———	———	andalusite.
garnet,	garnet,	garnet.
staurolite,	staurolite,	———
tourmaline,	———	tourmaline.
pleonaste,	spinel,	pleonaste.
corundum,	corundum,	corundum.
margarite,	———	———
ripidolite,	———	———
rutile,	rutile,	rutile.
sphene,	anatase,	———
ilmenite,	ilmenite,	ilmenite.
zircon,	zircon,	zircon.
magnetite,	magnetite,	magnetite.
pale augite (on contact),	hypersthene,	———
scapolite (on contact),	———	———
zoisite,	calcite,	several undetermined minerals.
epidote.	apatite.	
18 species.	14 species.	9 species.

* Mikroskopische Physiographie der massigen Gesteine. 2d ed., p. 128.

† Geologische und petrographische Beiträge zur Kenntniss des Harzes. Jahrb. d. kön. preuss. geol. Landesanstalt für 1880.

‡ Die Kersantite des Unterharzes, I Theil, ib. für 1886, pp. 44–104.

§ The writer is indebted to Dr. Koch for an interesting suite of specimens illustrating the various kinds of inclusions found in the Harz kersantites. A study of these shows many points of difference, but nevertheless a strong general likeness to the Cortlandt inclusions.

Lossen and Koch also mention *cordierite* as an abundant constituent in the kersantite of Michaelstein, although this mineral does not appear in the inclusions.*

II. *Contact-metamorphism in the Limestone.*

The limestone beds associated with the gneisses and mica schists of Westchester County have been carefully mapped and described by Professor James D. Dana.† They are regarded by him as belonging to the Green Mountain system and as probably of Lower Silurian or Cambrian age. Some of this limestone appears within the limits of Cortlandt township, but it falls within the scope of this paper only in so far as it has been modified by the action of the intrusive rocks of the Cortlandt Series.

The western edge of Verplanck Point, which projects into the Hudson River south of Peekskill, is formed of the Tompkins Cove limestone, so admirably exposed in the large quarries on the opposite side of the river. At the southern end of the point the limestone is in contact with the massive rocks, which here display in the most unmistakable manner the evidence of their eruptive character. This fact is admitted by Professor Dana, although he is inclined to regard the dykes there exposed as softened or fused sedimentary material rather than truly exotic intrusives.‡

* At the close of his series of articles on the Westchester County rocks, Professor Dana has very admirably summarized all the essential contact phenomena displayed at Cruger's. (This Journal, III, xxii, p. 314, Oct. 1881.) He here also advances four considerations which he believes to be adverse to the idea that the contact-phenomena were produced by the action of an eruptive rock. These considerations are briefly as follows:

1. The crumpling of the schist must have been produced at the time of its metamorphism.
2. An intruded rock would have been too feeble an agent to produce this.
3. The increase of metamorphism would only have needed an increase in temperature, and this may have been caused by the crumpling of the strata.
4. Staurolite and fibrolite are widely distributed through the mica schists.

Evidently the metamorphism of the original rock—whatever its character—*into a mica schist* must have taken place at the time of its folding and crumpling. Now it is by no means certain that the forcible intrusion of a large body of molten rock, far below the surface, may not have exerted a pressure in accordance with laws of hydrostatics sufficient to have caused the local puckering to be seen at Cruger's. But this does not necessarily have any bearing on the question. The original rock may have been crumpled and changed to a mica schist by some orographic force, as Professor Dana thinks probable, and subsequently have undergone a further contact-metamorphism by the agency of the Cortlandt eruptives. The intrusion of the massive rock itself may have been—probably was—*the result* of orographic movements. This intrusion may or may not have caused the puckering, but the progressive metamorphism observed at Cruger's bears such a direct relation to the contact line that the conclusion seems unavoidable that at least the mineralogical changes above described are directly due to the influence of the eruptive rocks

† On the Geological Relations of the Limestone Belts of Westchester County, N. Y. This Journal, 1880 and 1881, vols. xx, xxi, xxii.

‡ This Journal, III, xx, pp. 200–203 and 216, Sept., 1880.

Near the foot of Broadway in Verplanck the limestone fragments occur imbedded in the norite as figured by Professor Dana,* while just behind and beyond the hotel branching dykes of the massive rocks, varying from a fraction of an inch to many yards in width, penetrate the limestone in different directions, though in the main they follow the direction of its bedding. The microscope shows that these dykes belong to many different rock types, as for instance gabbro (Nos. 109, 111), mica-hornblende-diorite (No. 80), hornblende-diorite (Nos. 82 and 83) and mica-diorite (No. 81).

The metamorphic action extends but a small distance from the actual contact, but is always unmistakable in its nature. The limestone is in almost all cases bleached and is frequently rendered more coarsely crystalline. There are new contact-minerals developed in it, among the most common of which are hornblende and pyroxene, both rich in lime and of a pale color.

In the narrowest dykes, the nature of the eruptive rock is also considerably modified. In one of these (No. 77), the entire width of the dyke (only one-eighth of an inch) is contained within the thin-section. The intrusive material consists of brown hornblende, biotite, triclinic feldspar, apatite and an abundance of a brightly polarizing, uniaxial, negative, colorless mineral, which is probably scapolite. The brown hornblende is concentrated along the edges of the dyke and often stands perpendicular to its walls. The limestone beside the eruptive material is highly crystalline and contains colorless pyroxene and muscovite.

In some cases, as for instance in a section of Professor Dana's collection, the metamorphic action is extremely slight even when seen under the microscope. This particular section contains the contact between a mica-hornblende-diorite and limestone. The only change in the former is a concentration of hornblende along the contact line, while the limestone has become slightly more crystalline and contains oval spots of serpentine.

In the cutting exposed on the West Shore Railroad at Stony Point, a narrow band of limestone is seen between the masses of mica-diorite and peridotite, which, but for this, come here in contact. This limestone is very crystalline and is filled with minerals doubtless derived from the eruptive rocks. There is a pale pyroxene (malacolite), a light green hornblende, zoisite, sphene, and quite abundant scapolite.

At the conclusion of this series of papers, it may be advisable to summarize the evidence in favor of the eruptive (igneous)

* This Journal, III, xx, p. 202, fig. 5.

origin of the massive members of the Cortlandt Series; this can be done as follows:—

1. The general character of the rocks themselves, which, both in structure and mineralogical composition, agree with well recognized eruptive types.
2. The differentiation of massive rocks into facies which occupy irregular areas; i. e. there is nothing in the alternation of the different types to suggest an originally sedimentary structure.
3. Occurrence of the massive rocks in well-defined dikes
    (*a*) in other massive rocks. Montrose Point and Stony Point.
    (*b*) in mica schist. Stony Point.
    (*c*) in limestone. Verplanck Point.
4. Occurrence of angular rock fragments (inclusions) in the massive rocks.
    (*a*) of crystalline schist. Cruger's.
    (*b*) of limestone. Verplanck Point.
5. Production of contact phenomena in the stratified rocks adjoining the massive ones:
    (*a*) in crystalline schists. Cruger's. Stony Point.
    (*b*) in limestone. Verplanck Point.

It is probable that the Cortlandt Area was once the scene of prolonged volcanic activity from several vents. There is, however, every reason to suppose that the rocks now exposed solidified at a considerable depth below the surface and have since been brought to light by erosion. This is indicated:—

1. By the coarse-grained structure of many of the massive rocks themselves, which gives to them a plutonic rather than a volcanic or superficial character.
2. By the absence of any tuff deposits or topographical resemblance to volcanoes.
3. By the presence of a marked contact zone, such as is only produced around deep-seated eruptive masses, where the enclosed vapors cannot readily escape.

The seat of intensest action would seem to have been near the center of Cortlandt township, where norite is the prevailing rock. The most diverse types are peripheral in their distribution, especially toward the west and south. In these quarters also occur frequent remains of the original country rock in the way of bands of limestone or patches of mica schist. These have all suffered more or less intense metamorphism. It also seems probable that the iron and emery beds along the southern and eastern portions of the massive area, are to be regarded as the result of metamorphic action upon preëxistent material.

Petrographical Laboratory, Johns Hopkins University, Baltimore, May, 1888.

Explanation of figures in Plate VI.

Fig. 1. Typical, unaltered mica schist. River bank near Cruger's Station ("*l*" on the map), No. 21. Section cut approximately parallel to the foliation, shows the biotite mostly in basal sections of varying thickness. Large flakes of muscovite irregularly scattered through the field. Occasional crystals of tourmaline and zircon. Groundmass mostly a granular aggregate of quartz with very little feldspar. ($\times 30$).

Fig. 2. Fibrolitic schist, collected a short distance north of the last on the line of Section I (M. of Professor Dana's collection). Fibrolite very abundant in large sheaf-like bundles, and also in radiating tufts, garnet and biotite. Groundmass composed of coarse grains of quartz with some feldspar. ($\times 30$).

Fig. 3. Staurolitic mica schist ("*o*" on the map) No. 25. Large crystals of yellow staurolite with irregular boundaries and the usual quartz inclusions at their center scattered through a matrix of quartz and biotite. Some fibrolite in radiating tufts. ($\times 30$).

Fig. 4. Fibrolitic schist from very near the contact ("*p*" on the map) No. 37. Rock very largely composed of fibrolite in feathery tufts, bundles and sheaves. Matrix almost wholly a brown mica. There also occur in lesser quantity cyanite, garnet and staurolite. ($\times 30$).

Fig. 5. Black inclusion in the mica-diorite (near "*s*" on the map) No. 29. Composed mainly of pleonaste in small octahedral crystals among which are scattered larger crystals of colorless corundum. Where the section is sufficiently transparent, feldspar and biotite in small quantity may be recognized. ($\times 30$).

Fig. 6. Inclusion in mica-diorite ("*s*" on the map) No. 12. The most important constituent is margarite in colorless crystals. Other minerals are green mica (ripidolite), biotite, quartz, feldspar and magnetite. Tourmaline and epidote also occur in these inclusions, although they are not represented in the figure. ($\times 30$).

Art. XXVII.—*The Sedentary Habits of Platyceras*; by C. R. Keyes.

The genus *Platyceras* was founded by Conrad* in 1840 for a Paleozoic group of gasteropodous shells "sub-oval or sub-globose, with a small spire, the whorls of which are sometimes free and sometimes contiguous; the mouth generally campanulated or expanded." Hitherto these fossil shells had been referred to the genus of modern Mollusca *Capulus*, proposed by Monfort† in 1810. Conrad's name, however, for this fossil group was not until within the past few years generally accepted, preference having been given by most European writers and also by some American authors to *Acroculia* of Phillips,‡ notwithstanding the fact that the type of Phillips's genus was a typical form of *Platyceras*. Although the forms of this genus present so few classificatory characters of definite specific value more than three hundred species have been described—over one-half of which are from America. In this genus, as in many other Paleozoic genera, numerous species have been based not on any apparent distinctive character, but seemingly simply on their occurrence at different geological

* Ann. Rep. Palæ. N. Y., p. 205. † Conch. Syst., vol. ii.
‡ Palæ. Foss. Cornwall, etc., 1841.

horizons; and this has given rise to the establishment of many species which are unquestionably invalid. The synonymy of the species of *Platyceras* when fully worked out will doubtless result in quite an extensive numerical reduction of the species. In the absence of better defined characters for specific distinction considerable importance has been attached to the configuration of the peristome, but even this character in the majority of the species of this genus now appears to have little, if any, classificatory value. A careful comparison of a large series of different species of *Platyceras* reveals the fact that the apertural margin in various specimens of the same species often presents considerable variation: a phenomenon not to be entirely unexpected in a group so closely allied to the modern *Capulus*, from which some writers even now question the propriety of generically separating *Platyceras*. Among the living *Calyptræidæ* it has been observed that both color and form are to a great extent dependent upon individual environment, and hence among forms of the same species there may be many varietal phases. It has further been noted that the majority of the members of this family attach themselves, while yet quite young, to stones and shells of other Mollusca and, having once found a suitable situation, seldom, if ever, remove from the spot where they first settled. The character and contour of the surface on which they have settled would therefore determine the form and outline of the apertural margin. The sedentary habits of the modern representatives of this group of Mollusca would be suggestive of analogous habits among their fossil congeners. Notwithstanding the comparative abundance of *Platyceras* in some of the Paleozoic strata of both this country and Europe direct paleontological evidence of the sedentary habits of this group is not often met with; yet the instances presented, independent of their bearing upon *Platyceras*, are of unusual significance as furnishing a solution to certain important morphological problems relative to the paleozoic crinoids. From time to time paleontologists have mentioned the occurrence of *Platyceras* attached to crinoids, and numerous explanations have been advanced, but it was not until 1873* that the probably correct solution was given. A discussion of the various explanations offered prior to this date is not necessary since some of them have been fully considered by Meek and Worthen,† who have also pointed out clearly the improbability of the claims of the Austins‡ in their elaborate and highly imaginary account, and others, that the crinoids perished while in the act of devouring the *Platyceras*. Not only is this view highly improbable but its absurdity is only too manifest when the character of the food of both these

* Geol. Ill., vol. v, p. 334 *et seq.* † *Loc. cit.* ‡ Recent and Fossil Crinoidea.

gasteropods and their associated crinoids is taken into consideration, for there was presumably no very great difference in the habits of the living and their closely allied fossil species. And it is known that living crinoids subsist chiefly upon animalcules and microscopic plants, and that the food of most, if not all, of the *Calyptræidæ* is of a similar nature.

The extensive crinoidal collections of Mr. Charles Wachsmuth contains numerous examples of palæocrinoids with attached *Platycerata*, an examination of which has fully and satisfactorily corroborated many of the observations of Meek and Worthen. The species examined were chiefly *Arthroacantha punctobrachiata* Williams, *Ollacrinus tuberosus* Lyon and Cassidy, *O. typus* Hall, *Platycrinus hemisphericus* Meek and Worthen, *Physetocrinus ventricosus* Hall, *Actinocrinus* (sp.?). It will be noticed that in the genera to which the first five species belong the vault is very much depressed or almost flat and the ventral aperture is a simple opening; while in the last genus the ventral opening is situated at the extremity of a prolonged "proboscis." In nearly every case observable the *Platyceras* completely covers the opening in the vault and this fact has led many of the earlier writers to suppose that the crinoid was feeding upon the *Platyceras* when it perished; it has also suggested that the *Platyceras* may have fed in part at least upon the excrementitious matter from the crinoid. In the case of *Actinocrinus*, the *Platyceras* was attached to the vault at the base of the "proboscis," and was nearly hidden from view by the arms of the crinoids. Meek and Worthen have pointed out* and it is clearly observable in nearly all the examples examined, that the attachment of *Platyceras* to the various species of crinoids is not the result of accidental pressure but that it was actually attached during life, as is shown by the sinuosities in the lip of *Platyceras* corresponding exactly to the irregularities of the surface to which the shell was attached. Of the Crawfordsville species *Platycrinus hemisphericus* and *Ollacrinus tuberosus* when having *Platyceras* attached, *Platyceras infundibulum* M. and W. is usually associated with the former and *P. æquilatera* with the latter. In the absence of direct proof to the contrary this has led Meek and Worthen to suggest that "it is worthy of note that it is always a sub-spiral *Platyceras* that we find attached to this crinoid (*O. tuberosus*) so that here at least it would seem that each of these crinoids has its own particular species of *Platyceras*." The recent examination of an extensive series of both of these species has disclosed in a number of instances the occurrence on *Platycrinus hemisphericus* of *Platyceras æquilatera* instead of the more common *Platyceras infundibulum*;

* Geol. Ill., vol. iii, p. 386.

and this would appear to be indicative of an accidental selection by the *Platyceras* for attachment to any particular crinoid, rather than each crinoidal species possessing its own particular species of *Platyceras*. The latter case would be suggestive of the *Platyceras* being more or less parasitic in its habits, which in reality it doubtless was not.

ART. XXVIII.—*On Edisonite, a fourth form of Titanic acid;* by W. E. HIDDEN.

THE original specimen of the mineral here described was discovered by the writer in the summer of 1879, at the Whistnant Gold Mine, in Polk County, North Carolina. It was found in the concentrations of placer washings and was associated with gold and well-preserved crystals of zircon, xenotime, monazite, rutile and a dozen or more commoner mineral species. The orthorhombic symmetry of the mineral was early noticed, but I was unable to decide which direction to make the vertical axis of the crystal. Referring to my notebook I find two sketches made from this specimen. Figures 1 and 2 are copies made from these drawings. The angles I then obtained were unsatisfactory, being made with a hand goniometer, yet they served to prove the orthorhombic character of the crystal; these angles are given below. The other characters of the mineral noted are as follows: Cleavages parallel to three forms or six cleavage planes in all. Fracture small conchoidal. Hardness about 6 (scratches glass); specific gravity =4·26. Luster resinous to adamantine. Color bronze-yellow to golden brown. Streak yellowish white. Insoluble in acids. Unchanged before the blowpipe with soda; but with borax gives a brownish bead much like the color of the original mineral.

The above comprises all the results obtained on the specimen up to 1886, when I sent part of it to Professor DesCloizeaux, for careful measurement of angles and chemical examination. A letter from him, dated May 8th, 1886, contained the following information:

". . . . In regard to the 'unknown substance,' after having made a careful examination I have found, with a new objective and a new illuminator of the Bertrand microscope, that the mineral has but a single optic axis, or two axes extremely close, with bisectrix perpendicular to the acute edge of 40°. This edge shows one positive axis with cross divided with difficulty. My friend Damour, so skillful in determining small quantities, can only find titanic acid. Therefore, on account of the easy cleavages following $a\frac{1}{3}$, less easy it seems to me than

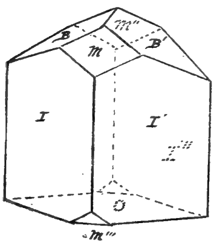
those following $e\frac{1}{3}$ and of the angle $m \wedge m$ always varying somewhat from 90° I incline to believe that we have to do with a dimorphous form of rutile. . . . . . I have adopted the symbols $a\frac{1}{3}$ and $e\frac{1}{3}$ because in rutile the form $a\frac{1}{3}$ (=3 of Dana) is unknown and it would give with the base an angle of 139° 48′. It has always been said that dimorphous bodies have very closely related crystalline forms and we have here an example of a very near approach between the two forms. On the fragments you have sent me I notice that the faces $a\frac{1}{3}$ and $e\frac{1}{3}$ differ in color and brilliancy. I trust you will succeed in procuring some new specimens of dimorphous rutile."*

I add to my own figures (1 and 2) and approximate angles, the figure (3) given by DesCloizeaux and the angles observed and calculated by him. The axial ratio given by him is

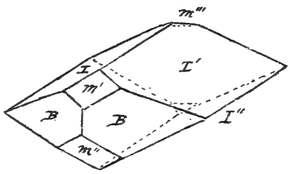
$$\breve{a} : \bar{b} : c = 0{\cdot}99275 : 1 : 0{\cdot}92337.$$

The only natural faces observed are *I* and *O* (fig. 1), the others are cleavage planes.

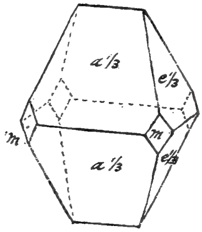
1.



2.



3.



Hand goniometer, Hidden.				Reflecting goniometer, DesCloizeaux. Calculated.	Observed.
$I \wedge I'$	= 140° approx.	=	$a\frac{1}{3} \wedge a\frac{1}{3}$	= 140° 34′........	140° 34′
$B \wedge B'$	136° "		$e\frac{1}{3} \wedge e\frac{1}{3}$	140° 18′........	140° 24′
$I \wedge m$	133° "		$a\frac{1}{3} \wedge m$	131° 55′........	131° 49′
$m \wedge m'''$	90° "		$m \wedge m$	90° 25′........	90° 25′
$m \wedge m'$	90° "		$m \wedge m$	89° 35′........	89° 32–3′
$B \wedge m$	130° "		$e\frac{1}{3} \wedge m$	131° 30′........	131° 42′
$I' \wedge I''$	40° "		$a\frac{1}{3} \wedge a\frac{1}{3}$	39° 26′........	38° 52′

$a\frac{1}{3} = I$, $e\frac{1}{3} = B$, $m = m$, Faces of *cleavage*.

Since Damour found only TiO_2, and this, if correct, would prove it to be a *fourth form* of this acid, I questioned the result because of its seeming improbability. A few careful tests made by Mr. Mackintosh have confirmed the conclusions of Damour. Recently Mr. S. L. Penfield has kindly undertaken a complete analysis of the mineral, and I am happy to be able to add his statement of the very satisfactory results obtained. Mr. Penfield says:

"The specific gravity, taken with great care on 0·155 grams of the mineral, was 4·285. Owing to the scarcity of material

* A notice giving the above results was published by Professor DesCloizeaux at the time. Bull. Soc. Min., vol. ix, No. 5.

only 0·0770 grams were used for the chemical analysis. In order to determine how much reliance could be placed on an analysis made upon so small a quantity an equal weight of rutile was analyzed by exactly the same method, and it may be said here that the behavior of the two was exactly similar throughout. The method of analysis was as follows: The finely powdered mineral was decomposed by fusion with acid sulphate of potash. The solutions in water which were turbid, were treated with strong hydrochloric and a little sulphuric acid, evaporated to dryness and heated till all the hydrochloric acid was driven off; when treated again with water the solutions were perfectly clear; they were diluted to a volume of 500 c. c., a solution of SO_2 in water added to reduce any iron, and then boiled for an hour and a half, replacing the water as it evaporated. The precipitated TiO_2 was allowed to settle and was then filtered and washed. The oxide ignited over a blast lamp, lost nothing by further ignition with ammonium carbonate. The filtrate was evaporated to small bulk, the iron oxidized with nitric acid and ammonia added in excess; this caused a slight precipitate, which in the rutile was light colored and after weighing gave with the borax and salt of phosphorus beads chromium reactions; in the edisonite it was red and gave iron and probably titanium reactions. The results are as follows:

	Rutile.	Edisonite.
TiO_2 precipitated by boiling	·0756	·0744
Trace of oxide from the filtrate	·0022	·0033
Loss on ignition	·0002	·0001
	·0780	·0778
Weight of mineral taken	·0780	·0770

These results show that the edisonite is a nearly pure TiO_2 like rutile. The only other constituent that could be detected was a trace of iron."

Careful search at the above locality, since the finding of the above described specimen, has failed to bring to light more than one additional example, and that a minute one found last summer; the writer thinks however, he has lately identified this mineral on the Pilot Mt. in Burke Co., N. C., with the same associations.

Since the composition of this mineral is thus proved to be pure titanic oxide, and since the crystallization seems to distinguish it from the three forms of TiO_2 already known, the mineral must be regarded as a new one and sufficiently characterized to merit a name. I therefore propose for it the name *Edisonite*, after Mr. Thomas Alva Edison, through whose generosity the journey was made on which this mineral was found, and also because of his always ready interest and help toward scientific research.

Art. XXIX.—*On two new masses of Meteoric Iron;* by George F. Kunz. With Plate VII.

1. *Meteoric Iron from Linnville Mountain, Burke Co., North Carolina.*

A mass of meteoric iron* was found on Linnville Mountain, Burke Co., N. C., (long. 81° 35′ W. of Greenwich, lat. 35° 40′ N.), about the year 1882. It was handed to a country blacksmith in the vicinity who sold it to a tourist miner, and by him it was sold to Mr. Norman Spang, of Etna, Pa., who, not being a collector of meteorites, has kindly allowed it to come into my possession.

This meteorite weighs 428 grams; the original weight was 442 grams ($15\frac{1}{2}$ ounces), the balance having been used for analysis and for etching; it is $2\frac{3}{5}$ inches (65^{mm}) long, $1\frac{2}{5}$ inches (35^{mm}) high and $2\frac{1}{2}$ inches (38^{mm}) wide. One side is rather rough and the other pitted with very shallow pittings. Traces of the black crust of magnetic oxide of iron are still visible, and although the mass is not rusted, yet small drops of chloride of iron have collected in the deep clefts, and in one of them was found a spider's egg case, suggesting either that the iron is a recent fall or had been found on the surface of the ground. See figure 1 on Plate VII, natural size.

In cutting a piece from the lower side, the blacksmith has destroyed considerable of the surface as well as the crust, on account of the toughness of the iron. The iron admits of a very high polish, yielding a rich nickel color, which under the glass and by reflected light, shows an apparent network of two distinct bodies.

When bromine water or diluted nitric acid is applied to a polished surface of the iron it blackens and does not show the Widmanstätten figures. See figure 2 on Plate VII magnified two diameters. If this black deposit is washed off an orientated sheen appears which resembles that of the Green County iron described by Blake† and the iron in the Port Orford, Oregon, meteorite, as figured by Brezina and Cohen in "Die Structur und Zusammensetzung der Meteoreisen, etc."‡ Almost the entire surface has, under the glass, the appearance of a meshwork of which the irregularly rounded centers have been eaten out. At a few places on both sides of a crack is a small piece of troilite 3^{mm} by $1\frac{1}{2}^{mm}$, through which are scattered small patches of meteoric iron that after etching

* Exhibited at the New York Academy of Sciences, Dec. 5th, 1887.

† This Journal, III, vol. xxxi, p. 41.

‡ Stuttgart, 1876, Lieferung I, Tafel VI.

exhibit beautiful octahedral markings so delicate as to be invisible to the naked eye, and somewhat like those of the Tazewell, Claiborne Co., meteorite, though not more than one-tenth the thickness.

The following analysis was kindly furnished by Mr. J. Edward Whitfield, of the United States Geological Survey, through the courtesy of Prof. F. W. Clarke.

	Linnville, Whitfield.	Tazewell,* Smith.	Bear Creek,† Smith.
Iron	84·56	83·02	83·89
Nickel	14·95	14·62	14·06
Cobalt	0·33	0·50	0·83
Copper	0·0	0·06	trace
Sulphur	0·12	0·08	----
Carbon	trace	----	----
Phosphorus	"	0·19	0·21
Magnesium	----	0·24	----
Silica	none	0·84	----
	99·96	99·57	98·12

It most closely resembles the Tazewell, Claiborne and Bear Creek, Col., meteorites in composition. I herewith take pleasure in thanking Mr. Norman Spang for his kindness in allowing me to secure the iron and facts of finding, Mr. J. Edward Whitfield and Prof. F. W. Clarke for the analysis.

2. *Meteoric Iron from Laramie County, Wyoming.*

The Laramie County mass of meteoric iron‡ was found by Mr. Edward J. Sweet, in the latter part of January, 1887, while he was prospecting in the Silver Crown District, almost in the center of town 14, range 70, between the middle and south fork of Crow Creek, Laramie County, Wyoming Territory, about 21 miles west of Cheyenne, in long. 105° 20′ west of Greenwich and north lat. 41° 10′. When found it was half buried in decomposed granite and earth. After being a ten days' wonder among the miners at the camp it was sent to Dr. Wilbur C. Knight, of Cheyenne, Wyoming, through whom it came into my possession.

In shape this mass somewhat resembles an anvil (see fig. 3, two-thirds natural size). It weighs 25·61 lbs., 363 oz. Troy (11·616 kilos.); and is 17·5^{cm} high, 14^{cm} thick at the center and 19^{cm} at the widest point. The entire surface is still covered with the original crust of magnetic oxide of iron, which has been slightly acted upon by the atmospheric agencies. No trace of chloride of iron was perceived. There is no exudation although it has been in my possession some months. The

* Original Researches, 1884, p. 439. † This Journal, II, vol. xix, p. 153.
‡ Exhibited and described at the New York Academy of Sciences, Dec. 5, 1887.

surface is irregularly pitted, the largest of the pits being 3^{cm} by 2^{cm} and very deep for their size. No troilite was observed either in the cutting or in the pitting. This iron is one of the Braunite group of Meunier.

When etched with dilute nitric acid this iron does not show the Widmanstätten figures, but under the glass the markings are seen to be similar to the Braunau Hauptmanndorff iron described by Tschermak* and Huntington,† (see figure 4). This beautiful structure is broken only by the thin layers of schreibersite, which divide a surface 25^{mm} square into over twenty-five irregular crystalline parts.

The specific gravity is 7·630. The following analysis was kindly made by Mr. Howard L. McIlvain:

	Silver Crown.	Rowton,‡ Flight.	Charlotte,§ Smith.	Jewel Hill,‖ Smith.
Iron	91·57	91·25	91·15	91·12
Nickel	8·31	8·582	8·05	7·82
Cobalt	trace	0·371	0·72	0·43
Phosphorus	·07	----	0·06	0·08
Carbon	trace	---	----	----
	99·95		99·98	99 45

It approaches more closely to the Rowton, Charlotte and Jewel Hill meteorites in composition.

I take pleasure in thanking Dr. Wilbur C. Knight for assistance in securing the iron, and Mr. Howard L. McIlvain for the analysis.

ART. XXX.—*Experiments on the Effect of Magnetic Force on the Equipotential Lines of an Electric Current;* by E. H. HALL, Assistant Professor of Physics in Harvard College.

[Continued from the August number of this Journal, p. 146.]

THE next to the last column in this table (August number) shows that the intensity of magnetic induction in the thin cross remains throughout very nearly the same as that of the magnetizing field, but the intensity of magnetic induction in the thick cross, about $1\frac{3}{4}$ times as great as that of the magnetizing field when this is weakest, falls to a value about $1\frac{1}{3}$ times as great as that of the magnetizing field when this is strongest. The intensity thus attained is about 22000 c. g. s. units, a notably high one.¶

* Sitzungsber. Akad. Wiss., Wien, lxx, Abth. i., p. 449.

† Proc. Amer. Acad. Arts and Sciences, May 12, 1886, p. 478.

‡ Trans. Royal Soc., Feb. 9, 1882. § This Journal, III, vol. x, p. 349.

‖ Ibid., II, xxxix, p. 24.

¶ There may be a constant error of several per cent in the values of magnetic induction given in this article, as the area of the little test-coil used between the poles of the magnet is difficult to measure accurately.

It remains to give an account of experiments with other metals in which the effect of shape of cross-section has been in some measure tested. With these experiments will be described certain others closely related to them.

Cobalt.—Wide and narrow: Two crosses of cobalt were cut from a rolled bar of this metal furnished by the courtesy of Mr. Joseph Wharton of Philadelphia. In each cross a line which had been transverse to the original bar became the direction of the main current. The approximate dimensions were as follows:

	Width of		Thickness of	Length of	
	Main part.	Arms.	effective part.	Main part.	Arms.
No. 1	$5{\cdot}0^{mm}$	$1{\cdot}8^{mm}$	$0{\cdot}80^{mm}$	12^{mm}	2^{mm}
2	0·5	0·7	0·77	12	5

These crosses were compared in a magnetic field of intensity about 10700. The visible effect was large and the test was easily made. The result was $\frac{\text{R. P. of No. 2}}{\text{R. P. of No. 1}} = 1{\cdot}12.$

The question arose whether any large part of the superiority shown by the narrow cross could be attributed to a greater heating of this cross by the direct current. Experiment convinced me that this was not the case.

The R. P. of No. 1 appeared from a rough test to be about $\frac{4}{3}$ times as great as that of a very thin cross of cobalt taken from the same bar, and to be described hereafter. This discrepancy is hardly significant in view of the roughness of the comparison and the uncertainty as to the thickness of the thinnest cross.

Thin cross; field of varying strength: A part of the cobalt bar already mentioned was heated and hammered to reduce its thickness. The reducing process was continued by grinding, etc., until finally a cross was obtained, the dimensions of which were approximately as follows:

	Width of		Length of	
Thickness.	Main part.	Arms.	Main part.	Arms.
$\cdot048^{mm}$	$11{\cdot}5^{mm}$	$2{\cdot}0^{mm}$	28^{mm}	4^{mm}

The value given for the thickness is a rough estimation of the average thickness between the arms. It may be wrong by 10 or 15 per cent in either excess or defect.

This piece of metal was, like most others that I have used, imbedded in a cement of bees-wax and rosin on a glass plate. It was placed between the poles of the magnet in a narrow tank through which water flowed to control the temperature of the metal. The character and results of the examination are set forth in the following table, where M is the intensity of the magnetic field in absolute units:

Date.	Temp.		M.		R. P. × 10^6	
Aug. 3, 1885	21·9°	22°	795	793	11440	11560
" 4 "	22·1°		792		11680	
" 5 "	22°	22°	1716	1688	11650	11610
" "	22°		1660		11570	
" 6 "	21·7°	22°	5261	5243	11670	11680
" "	22·°		5224		11690	
" 7 "	22°	22°	9241	9186	11090	11170
" "	21·9°		9131		11240	
" 5 "	2·9°		1687			10940

The main current through the cross was always about 0·1 absolute unit.

The two determinations of M on Aug. 7 were not entirely independent, they being made from three sets of observations, of which the second set was used with the first to give the first value of M and again with the third to give the second value of M. The one test at a low temperature, 2·9°, was probably less reliable than the others.

The fall of R. P. with fall of temperature appears to be about $\frac{1}{3}$ per cent per 1° C.

The increase in the R. P. column in fields ranging from 793 to 5243 is perhaps purely accidental. The small but decided fall in going from the field 5243 to the field 9186 undoubtedly shows a true decline. The significance of this decline should not be overlooked. The intensity of magnetic induction through this very thin piece of metal must in all cases have been almost exactly as great as that of the magnetizing field. Hence the decline in the R. P. as the intensity of the field increases means a failure of the transverse effect in the cobalt to keep pace with the intensity of magnetic induction through the same.

In this Journal for February, 1885, I gave as the R. P. of cobalt 2460×10^{-6},* with a fall of nearly 1 per cent for a fall of 1° C. The specimen that gave these values was very different in character from that used in the experiments of this article. It was cast cobalt and was quite brittle. It probably contained little, if any, iron, but was known to contain nickel. The specimen used in these later experiments is known to contain some iron and some carbon. I do not know whether it contains nickel. It is harder than most kinds of iron, but not so hard as tempered steel. It is not brittle. Treatment which would temper or anneal steel produced no marked effect upon it.

The impurities of the first specimen probably diminished its R. P. It is not known what effect the iron and carbon

* This is the *corrected* value. See explanation in this Journal for August, 1888.

have in the second. In view of the great difference between the R. P. of soft iron and that of tempered steel, the latter being, in some cases at least, about four times as great as the former, the difference in the behavior of these two specimens of cobalt should not, perhaps, excite surprise.

An experiment was made to determine how much of the effect produced upon the equipotential lines in this more recently used cross by a magnetic field of about 9000 would survive the removal of the cross from the field. It appeared that this permanent effect was rather less than 1 per cent of the temporary effect and in the same direction.

Nickel.—Thin Cross; field of varying strength: The specimen of nickel that gave the quantitative results relating to this metal which I have published in previous papers, was a piece of commercial nickel plating stripped from the surface upon which it had been electrolytically deposited. I had now at hand a thin sheet of rolled nickel quite different in character from this specimen, much softer and more pliable. Little is known concerning the purity of the first specimen. The second, which like the cobalt bar already mentioned was given me by Mr. Wharton, is probably much the purer of the two, although it shows a trace of iron. The thickness is about $0{\cdot}3^{mm}$. From this sheet a cross was made, of which the dimensions were approximately as follows:

Thickness between Arms.	Width of Main part.	Width of Arms.	Length of Main part.	Length of Arms.
$\cdot096^{mm}$	$11{\cdot}4^{mm}$	3^{mm}	28^{mm}	7^{mm}

With this cross:

Date.	Temp.		M.		R. P. × 10^6.	
Aug. 12, 1885	22·4°	22·5°	3595	3564	−9121	−9177
Aug. 12, 1885	22·6°		3533		−9234	
Aug. 13, 1885		22·4°		9152		−5776

The direct current through the cross was about 0·1 absolute unit.

It appears that the R. P. of this specimen of nickel is about two-thirds or three-fourths as great as that of the piece previously used, but the uncertainty which exists regarding the thickness of each prevents any accurate conclusion upon this point. The diminution of R. P. when M increases from moderate values to higher values is very marked in each. It is somewhat greater in the later specimen than in the earlier, in which there was, according to the experiments of 1881, a fall from about 12500 with M=3600 to about 8400 with M=9100. This diminution, like that noted with the thin cobalt and in certain cases with iron, indicates a failure of the transverse

effect to increase proportionally with the magnetic induction through the metal.*

As with the thin cross of cobalt, so with this thin cross of nickel an endeavor was made to detect a permanent rotation of the equipotential lines by a magnetic field of about 9000. No such permanent effect was discovered. If any existed, it was probably less than 1 per cent of the temporary effect.

Crosses varying in shape of cross-section: Two crosses were cut from a commercial cast-nickel electrode and worked to the following dimensions approximately:

	Width of Main part.	Width of Arms.	Thickness between Arms.	Length of Main part.	Length of Arms.
No. 1	6^{mm}	2^{mm}	$1·32^{mm}$	23^{mm}	4^{mm}
No. 2	0·5	0·5	3·93	20	6

The comparison of these two crosses was very rough, as the table here given will show. In this table M signifies, as usual, the absolute intensity of the magnetizing field; Tr. is the transverse current, not in absolute measure, the direct current being supposed constant throughout the whole series; and P is the R. P., not in absolute measure.

No.	Date.	M.		Tr.		P.	
1.	Sept. 26, 1887	8300		652		104	
"	" " "	5100		616		160	
"	" " "	3450	3330	420	439	161	175
"	" 27, "	3200		457		188	
"	" " "	2100		279		175	
"	" 28, "	1070		127		157	
2.	" 26, "	8300		226		107	
"	" " "	5100		230		177	
"	" " "	3450	3330	214	224	243	265
"	" 27, "	3200		234		287	
"	" " "	2100		212		397	
"	" 28, "	1070		160		586	

It appears from this table, rough as it is, that in weak magnetizing fields the R. P. of No. 2 is about four times as great as that of No. 1, that as stronger and stronger fields are used the R. P. of each diminishes, but that of No. 2 so much the more rapidly that in a field of 8300 the two are nearly equal. This accords well with the result of the somewhat similar tests made with Norway iron, and in this case, as in that, the difference in behavior of the two crosses appears to be entirely

* For further evidence upon this point, on June 28, 1888, having laid upon this nickel cross a single loop of wire, I made tests similar to those described in my article in this Journal last August as having been made with two crosses of iron. The magnetizing forces used were about 5500 and 10000 respectively. The result was approximately as follows: ratio of magnetic induction through the cross in the two cases 1·8; ratio of transverse current in the two cases 1·1.

attributable to the greater ease with which the thicker and narrow piece of metal becomes magnetized.

It would appear from the table as it stands that the thin cross has a maximum R. P. when M is something between 1070 and 5100, but the experiments were so rough that their testimony upon this point is very doubtful.

It might also be inferred from this table that the actual transverse current obtained from the thick cross had a maximum value when M was something less than 8300. This seemed to me not impossible, but the experiments made could not be regarded as proving it. On Jan. 6, 1888, I returned to this matter and tested the thinner of these two crosses with magnetizing forces about 13000 and 19000 c. g. s. units respectively. The transverse currents produced in these two cases were nearly equal, whence I conclude that if there is a maximum value of the transverse current for any particular high value of M, this maximum must be very obscure. It seems far more likely that the tranverse effect continues to increase with M, although very slowly indeed when M is very great.

Bismuth.—In the summer of 1887, after I had begun preparations for a more thorough study of bismuth than I had yet made, I was obliged to leave Cambridge. Messrs. Coggeshall and Stone, of the Harvard class of 1886, and Mr. W. C. Sabine, of the graduate department, took up the work for me. They sawed in two a thick cross of ordinary commercial bismuth about 28^{mm} long and $3{\cdot}6^{mm}$ wide, and obtained thus two crosses of which one was about $0{\cdot}86^{mm}$ and the other about $3{\cdot}13^{mm}$ in thickness. Their experiments, like those of Ettingshausen and Nernst,* indicate that the R. P. of bismuth is independent of the thickness, and show that when the intensity of the magnetizing field is increased from 4600 to 12000 the R. P. of bismuth falls off very considerably.

I have more recently made some experiments with the thinner of these two crosses. I find, as did Ettingshausen and Nernst, that magnetization in one direction may produce in bismuth a greater transverse effect than magnetization in the opposite direction. This dissymmetry appears from my experiments to be very small, if it exists, when the magnetizing field is comparatively weak, 4500 or less. The experiments of Dec. 31, 1887, did not show it in a field of 8300, or plainly in a field of 11800, but those experiments were less carefully made than subsequent ones and are entitled to less credit. According to these later experiments the dissymmetry is well-marked in a field of 8000 or 9000 and is still greater in stronger fields. It was not greatly changed by reversing the

* I have seen only that abstract of their article which appeared in the *Beiblätter* No. 5, 1887.

direct current through the cross or by reversing the facing direction of the plate between the poles.

On Dec. 31, 1887, observing the dissymmetry, which I did not remember reading of, to be very great in a field of about 19000, I cut off the direct current through the cross, and leaving the transverse circuit closed, tried the effect of the magnet upon the cross in this condition. When the magnet current ran in one direction, it had little, if any, effect upon the galvanometer in the transverse circuit; but when it ran in the other direction, it produced a deflection more than one-half as large as the dissymmetry which had been observed and in the right direction to account for it. When the transverse circuit was broken, the effect almost entirely disappeared, showing that the *direct* action which the electro-magnet exerted upon the galvanometer was very small. The poles of the magnet were about 3^{mm} apart in this case. The plate bearing the bismuth was not pinched between them, but it became warm enough to soften the cement to a certain degree. On Jan. 4th, with the poles about 7^{mm} apart, the magnet had a slight effect upon the transverse circuit, the direct circuit being broken, the change of deflection produced by reversal being in the same direction as on Dec. 31. Whether this small effect was unsymmetrical was not observed. This was after magnet and cross had been in use. At the beginning of operations on this day, while the poles were about 4^{mm} apart, there was no certain effect of this sort. I have no record of further observations upon this point, which certainly demands investigation. The deflections observed may possibly have been merely accidental, but I do not think they were so. In the June experiments the poles were always about 7^{mm} apart and wads of cotton were placed between the plate and the poles on either side.

Ettingshausen and Nernst state that the R. P. of "bismuth sinks almost to $\frac{1}{4}$ . . . . , when M increases from 1000 to 16000," and that in a very strong field the transverse effect actually diminishes when the field is made stronger. The R. P. of the specimen which I have used diminishes greatly as M increases, but in no case under my observation has an increase of M failed to produce an increase of the transverse current, due allowance being made for casual discrepancies. In the following table the column Tr. gives the relative values of the transverse effects obtained with the respective values of M. The results of Dec. 31, 1887 and Jan. 4, 1888 have been reduced, as nearly as may be, to the scale of the June results by making all agree when M is about 10500. The column following Tr. shows roughly the dissymmetry which has been described. The column headed P gives the

R. P., not in absolute measure. The values of M are in absolute measure, as usual.

Date.	M.	Tr.	P.
Dec. 31, 1887,	5000	69·5	139
" " "	8300	99· =(50+49)	119
" " "	11900	125· =(61·5+63·5)	105
" " "	14700	131· =(60+71)	89
" " "	19300	147· =(59+88)	76
Jan. 4, 1888,	7800	99· =(46+53)	127
" " "	13200	134· =(59+75)	101·5
" " "	17600	165· =(67+98)	94
June 27, 1888,	2260	34·7=(15·9+18·8)	154
" 25, "	4600	66· =(33+33)	144
" 26, "	8840	103·6=(48·3+55·3)	117
" 25, "	9800	113· =(51+62)	115
" 26, "	11900	128· =(58+70)	107

It appears from this table, which is certainly not entitled to full confidence in its details, that the R. P. of bismuth diminishes continually while M increases from 2260, the lowest value used, to 19300, the highest value used, the decrease being about one-half of the whole.

During the experiments in June a single loop of wire placed upon the bismuth strip was used, as such a loop had been used with iron, to test the magnetic induction through the metal. This quantity remained throughout proportional to the intensity of the magnetizing field, as it was expected to do.

In a field of about 5000 a test was made in which the direct current was varied from about ·12 to about ·5 absolute units. The transverse current was found to be nearly, at least, proportional to the direct current.

An unsuccessful endeavor was made to discover a permanent effect upon the equipotential lines in bismuth. The effect, if it existed, must have been very much less than one per cent of the temporary effect. The strength of field used was not recorded.

I have made no attempt to determine the effect of change of temperature on the R. P. of this metal.

In considering the fact that the R. P. of bismuth is very large, it should be remembered that the R. P. states the ratio of the transverse *difference of potential* to the *direct current.* This ratio is a useful one and is easy to find, but in order to indicate the amount of *rotation*, or change of direction of the equipotential lines, we need rather the ratio of the transverse difference of potential to the direct rate of fall of potential lengthwise of the strip examined. Bismuth has a very great electrical resistance, and the rate of fall of potential which

sends a given current through it is relatively large. Thus the R. P. of bismuth is perhaps 13000 times as great as that of gold and 800 times as great as that of nickel, but the equipotential lines in bismuth may not be rotated more than 200 times as far as those of gold or more than 80 times as far as those of nickel, in the same magnetic field.

Summary.

Experiments made with strips of steel, having longitudinal slits, are in agreement with predictions made in this Journal for February, 1885.

The transverse current from a very short strip is smaller than that from a long strip. (Already announced by Ettingshausen and Nernst.)

The table of coincidences given by Mr. Shelford Bidwell in his theory of the "Hall effect" is confirmed in the case of copper, iron and zinc, but exceptions to it are found in "French cold rolled steel" and aluminium.

In silver and bismuth the R. P. appears to be independent of the shape of cross-section of strips examined. (This conclusion as to bismuth already announced by Ettingshausen and Nernst.)

In the magnetic metals, iron, cobalt and nickel, the R. P. is greatly dependent upon the shape of cross-section of the specimen examined, being, in differently shaped pieces of a given metal in a comparatively weak magnetic field, apparently proportional to the intensity of magnetic induction through the respective pieces, and therefore much greater when the thickness of the piece is large compared with the width than when the opposite is the case. Therefore, although the mere possession of great magnetic permeability does not directly insure to a metal an especially large R. P., it may indirectly do so in a properly shaped specimen by insuring intense magnetization from a weak magnetizing force.

In the case of cobalt and of nickel there is some evidence that the R. P. attains a maximum value at a low or medium stage of magnetization. (Ettingshausen and Nernst make a similar remark concerning cobalt, iron and antimony.)

When a piece of iron, cobalt, or nickel is made to approach the state of "magnetic saturation," the transverse current obtained from it increases somewhat less rapidly than the magnetic induction through the metal, but experiments with very highly magnetized iron and nickel indicate that this transverse current tends toward a fixed limit rather than toward a maximum followed by a decline.

The R. P. of bismuth appears to diminish continually as the intensity of the magnetizing field rises from low to very high

values, but according to the experiments of this article the transverse current continues to increase throughout. (Ettingshausen and Nernst state that in their experiments with bismuth the transverse current actually declined in value when the magnetizing field was made very strong.)

Strong magnetization of bismuth in one direction produces a much greater transverse current than equally strong magnetization in the opposite direction. (This dissymmetry is noted by Ettingshausen and Nernst.)

A slight permanent rotation of the equipotential lines in cobalt is produced by magnetization, the direction of the effect being the same as that of the temporary effect. Nickel and bismuth were tested hastily in vain for a similar permanent effect.

The cobalt used in the experiments of this article has an R. P. about $4\frac{1}{2}$ times as great as that of the specimen previously used, and its R. P. is relatively much less affected by change of temperature.

Erratum: The sign — should be placed before the R. P. of silver in the August number of this Journal.

Art. XXXI.—*The Compression of Powdered Solids: A Note* by W. Spring.

Mr. Hallock, in a note inserted in this Journal,* has been good enough to recognize that his article entitled "The Flow of Solids" had through oversight been worded in such a way as to attribute to me the exact opposite of the conclusions I had drawn from my researches. In effect, whereas my experiments were made in view of determining whether certain characteristic properties of the liquid state, such as the faculty of welding together, etc., existed to a more or less minimized extent in solid bodies; Mr. Hallock, on the contrary, thought that the manifestation of these properties required previous liquefaction, so that I should have been wrong in assigning to the solid state some of the characteristic properties of liquids. The experiments he has made to verify this point have shown him that matter does really remain solid under strong compression, unless the bodies experimented with occupy, as is the case with ice, a smaller volume in the liquid than in the solid state. But in the latter part of his note Mr. Hallock again takes up the interpretation of my results and objects that the majority of the phenomena mentioned by me are not due to cubic compression, but rather to kneading under pressure.

* Vol. xxxvi, p. 59

I regret to be obliged to state that this new objection of Mr. Hallock's falls wide of its mark, like the first; this time it is a case of misunderstanding fortified by confusion, for he again repeats exactly what I have always asserted myself. I may, therefore, be allowed to explain in English this time, on account of the importance of the subject, and to avoid a recurrence of misinterpretations, which simply mean a loss of time and labor to everyone concerned.

When ten years ago* I began my researches on the compression of powders my sole object was to ascertain whether solid bodies possessed the property of welding when their particles are put in perfect contact. I desired to find out whether the phenomenon of regelation could be generalized, since Faraday had shown that contact, or an extremely slight pressure, suffices for its production, contrary to J. Thomson's view, who said pressure was the cause of the phenomenon. To realize this contact I thought it would be sufficient to press the bodies strongly together. To my mind, moreover, pressure was not an active agent in the matter, but only a means to the end, and I looked for the effects to contact alone. I have expressed myself thus on this point in nearly all my articles and it will therefore be sufficient to quote the following.

After having recalled† the fact that certain bodies, such as sodium nitrate, become a coherent mass when their powders are left undisturbed in a bottle for a certain space of time, and that the coherence of the mass depended upon contact, I said, "now, to increase the number of points of contact in a powdered body, it will be sufficient to put it under pressure heavy enough to cause the spaces between the fragments of the body to become filled up with their debris."

In another place‡ I said with regard to chemical reaction produced in my experiments—"one must not not lose sight of the fact that pressure is not a chemical agent to the same extent as heat or electricity." But as I have always thought that *contact* was brought about by compression I have often for the sake of brevity, spoken of "*welding due to pressure*" instead of always saying "*welding due to contact produced by compression.*" I now see that I was unwise in thus wishing to economize my time.

Besides, as conclusive proof that it is always to *contact* that I assigned welding phenomena, chemical reactions and also in part the diffusion of solids, there is the fact that I deemed it necessary to operate *in vacuo*, on account of failures in preliminary experiments made under the ordinary conditions. This is

* Bulletin de l'Académie de Belgique, II, xlvi, 1878.
† Bulletin de l'Académie de Belgique, II, xlix, p. 336, 1880.
‡ Bulletin de la Société chimique de Paris, vol. xli, p. 497, 1884.

what I said on this point in 1880,*—"so that in my preliminary experiments I had not operated *in vacuo* and must consequently have enclosed a notable quantity of air in the powders I compressed; this, besides preventing by its presence intimate contact between the particles of solid matter and hindering their union, etc."

If a different pressure is necessary for different bodies, it is solely because all bodies are not equally hard and not because pressure is the immediate cause of their welding.

Better yet, in all articles I have hitherto published on the chemical reactions of powdered solids I have shown the influence of time on the chemical phenomena, by leaving the compressed bodies undisturbed for more or less time, and out of the compressor. Here it is evident that pressure had nothing more to do, as it existed no longer. Quite recently I sent an article to the Zeitschrift für Physik u. Chemie, containing the results of experiments of this kind, which lasted four years, and showing how a chemical reaction can complete itself if the matter is allowed the time for diffusion. They also explain Mr. Hallock's results on the formation of alloys.

Finally, from a rational point of view, there is no reason for assigning an active part to pressure in the phenomenon of welding of bodies pure and simple, for the act of welding by no means brings about a permanent decrease in the volume of the matter, and from that moment it is not conceivable how it would possibly act otherwise than to establish as perfect a state of contact as possible. When Mr. H. states that welding takes place better by "motion under pressure" he is quite correct, for then the sliding of the grains on one another is eminently adapted to bring about perfect contact, because it expels interposed air and moisture, exactly as when clay is kneaded with the fingers.

We will now consider another view of the question, and examine the phenomena in which pressure acts as such, i. e. by the diminution in volume it causes in the matter operated on.

In my experiments published in 1880 I found that pressure brings about changes of allotropic state in bodies, when the least dense variety is compressed at a certain temperature. This is what pressure does. Many proofs now exist in favor of my conclusions. I will confine myself to quoting the fine researches of van't Hoff and Reicher on the shifting of the transition point by pressure.† These works have proved, in theory and practice, that rhombic sulphur passes to the monosymmetric variety at 95·6° at the ordinary pressure, and at 96·2° under 12 atm.; in other words 12 atm. pressure shift the point of transition 0·6°. This being the case 1,552 atm.

* Loc. cit. † Études de dynamique chimique, Amsterdam, 1884, p. 198.

would transform one variety of sulphur to the other at a temperature of 18°. So it is not very astonishing that I arrived at this result with 6,000 atm. pressure, and I acquired this fact four years prior to the works of van't Hoff and Reicher.

Again, pressure intervenes as such to *facilitate phenomena of solid diffusion*, when the volume of the matter after diffusion is smaller than that before diffusion. This I have already proved by numerous experiments, and will do so again in some I have already had in hand for a long time.

Mr. Hallock says on the subject of solid diffusion, "I think no one would expect . . . . . that a piece of copper and tin soldered together would diffuse and form a homogeneous bronze, nor would they expect that simple cubic static pressure would promote these reactions." To my mind Mr. H.'s opinion would be valid if the resulting bronze were less dense than the mixture of copper and tin, but in the opposite case there would be found, not a homogeneous bronze, but an interpenetration of the copper and tin at the surface of perfect contact, which would cease when the difference in density of successive infinitely thin layers, no longer had too high a value. This I have proved for the reaction between Na_2CO_3 and $BaSO_4$—and conversely—by studying the influence of time on the phenomenon and by showing that after some weeks a state of equilibrium is set up between the two bodies.*

I am aware that these results may appear extraordinary, but I must express myself categorically, as they represent facts. I will also add that on his side Mr. C. Roberts Austen† has obtained the blue alloy of copper and antimony at the surface of contact of the metals under pressure.

I have neither exhausted my reply nor the subject, but I will let things remain *in statu quo* at present, as I think I have sufficiently shown that I never attributed an active part to pressure in the welding of bodies, but that it intervenes as such only when a decrease in volume is necessary to produce a physical or chemical change of state at a given temperature, and also because I shall treat all those points in detail when uniting my results in book-form, after the termination of my experiments.

* Société chimique de Paris, 1884 et 1885.

† From a letter of Mr. Austen to the author.

ART. XXXII.—*Preliminary notice of Beryllonite, a new mineral;* by EDWARD S. DANA.

A FEW weeks since the writer received for examination some specimens of a mineral, the identity of which the finder had been unable to establish. A brief study made it clear that the mineral was new, and one offering a number of points of more than usual interest. A complete account of the mineral cannot be given until two or three months later, although the essential characters now known prove beyond a doubt that it is new; a preliminary notice at this time, therefore, seems to be desirable.

The specimens of the mineral in hand consist for the most part of isolated crystals, or parts of crystals, and broken fragments from the size of a pea upwards. The largest crystal found is nearly an inch across, and the largest broken mass has a surface of $1\frac{1}{2} \times 1\frac{1}{4}$ inches and a thickness of $\frac{3}{4}$ inch. The crystals belong to the orthorhombic system, or if they vary from this the deviation is very small. They are short prismatic or tabular in habit. They show one highly perfect cleavage, as perfect as that of topaz; a second nearly perfect but interrupted at right angles to it (measured 90° 0′), a third very imperfect corresponding to the third pinacoid plane apparently at right angles to the others, and a fourth, in the zone of the last two corresponding to a prism of very nearly 60°. Calling the plane of perfect cleavage the base, *c*, and making the cleavage prism, *m*, the unit prism, the second cleavage is brachydiagonal *b*, the third macrodiagonal *a*. The crystals are highly modified: in the prismatic zone there are seven prisms developed, the unit prism *m*, two macro-prisms and four brachy-prisms. The macrodome zone is also highly developed, the planes here corresponding very nearly in angle to the several prismatic planes measured from the same pinacoid plane *a;* in other words, the axes *b* and *c* are nearly equal. Only one brachydome has been noted. Of pyramids there are upwards of ten forming several prominent zones. Many of the crystals are twins and sometimes repeated twins with the cleavage prism, *m*, of nearly 60° as the twinning plane—these are contact twins. A few examples have also been noted of what are apparently penetration-twins having a pyramid in the unit series and inclined on *c* about 60° as the twinning-plane. If we make this the unit pyramid, *p*, the approximate axial ratio is:

$$\breve{a} : \bar{b} : \acute{c} = 0{\cdot}57 : 1 : 0{\cdot}94.$$

The other characters of the mineral are: hardness 5·5–6; specific gravity 2·84; fracture conchoidal; luster vitreous and very brilliant especially on the fracture, except on *c* pearly; color white to colorless; transparent to translucent. The fracture surfaces normal to *c* show a columnar structure. Before the blowpipe it decrepitates and fuses about 3 to a somewhat clouded glass, coloring the flame deep yellow. It gives colorless beads with borax and salt of phosphorus. No water was obtained in the closed tube. It dissolves entirely in hot hydrochloric acid, and the crust of salts obtained on evaporation gives a bright yellow flame, but the spectroscope shows nothing but the sodium line.

A few tests in the wet way showed that the mineral was a phosphate, sodium being present as a base, and also a metal whose oxide is precipitated by ammonia. The other experiments noted above give important negative evidence of the absence of most of the other bases that might be looked for. A test for fluorine with sulphuric acid gave negative results.

Since this examination was made a preliminary analysis by Prof. Horace L. Wells, of the Sheffield Scientific School, has shown the mineral to be an anhydrous phosphate of beryllium and sodium, with probably the formula $NaBePO_4$.

A complete analysis will soon be concluded, and as promptly as possible we propose to give an exhaustive account of this new mineral.

I would suggest the name *Beryllonite*, in allusion to the fact that it contains the rare element beryllium. The name of the gentleman to whom the credit of finding this new mineral is due, and that of the locality, are at his request withheld for the present.

SCIENTIFIC INTELLIGENCE.

I. Physics.

1. *Infra red Solar Spectrum.*—W. de W. Abney (Phil. Trans. Lond., 177, 1886) with the aid of a Rowland concave grating has improved his map of the infra red portion of the solar spectrum. He employed a special emulsion of bromide of silver in connection with a collodium emulsion. The developer consisted of a ferrous oxalate of greater strength than that formerly employed by him. The amount of vapor in the atmosphere exercises great influence upon the length of the infra red spectrum, and especially upon the group from A to wave-length 8200. Four strong lines, X_1 (8497) X_2 (8542), X_3 (8661) and X_4 (8816),

also Y (8986) and Y (8990) are not telluric lines but belong, according to the author, to metals with low melting points. The catalogue of lines given by Abney includes 590 lines.—*Beiblätter, Ann. der Physik*, No. 5, 1888, p. 351. J. T.

2. *Photometry of Color.*—A communication on this subject was read to the Physical Society, June 23, by Captain ABNEY. The apparatus consisted of a spectroscope and camera similar to those used by the author for the production of monochromatic light. A small shadow photometer served for the measurement. The screen was made of two parts—one the color to be tested and the other white or black according to the standard employed. The stick was arranged so that the shadows fell near the junction of the two parts. Light reflected from the surface of the first glass prism served to illuminate one shadow; and for the other, monochromatic light of any desired color could be used. The intensities were adjusted to equality by cutting off more or less of the stronger light by means of a revolving wheel with adjustable sectors, the opening of the sectors being a measure of the luminosity of the pigment. In another arrangement a double image prism was used to separate the spectrum into two parts. Monochromatic light from one part passed direct to the screen through sectors in a rotating wheel, and monochromatic light from the other spectrum was reflected on the screen at a sufficient azimuth to give a separate shadow, by means of two total reflection prisms. The losses by reflection were allowed for by obtaining the position of the adjustable sectors required to give equal intensities on a white screen. From the results color curves can be plotted for different pigments and templates constructed which, when rotated in the path of the spectrum, reproduce the corresponding color. In the course of the experiments many interesting observations on color blindness were obtained. Colors could be imitated whatever the source used to produce the spectrum.—*Nature*, July 19, 1888, p. 286. J. T.

3. *Heat Measurement.*—At a meeting of the Physical Society, Berlin, Dr. R. VON HELMHOLTZ exhibited a new form of bolometer, differing from that used by Langley. In the latter's instrument the alterations of electrical resistance produced by radiation are measured by introducing the exposed bolometer into one arm of a Wheatstone's bridge, a similar one protected from the light being introduced into the second arm of the bridge, while the other two arms contain a corresponding resistance. In the new bolometer constructed by Siemens and Halske all four arms of the bridge are composed of equal wires rolled up into a coil and of these coils 1 and 3 are illuminated, while 2 and 4 are protected, and then 2 and 4 are illuminated and 1 and 4 protected. By this means a four-fold sensitiveness is theoretically obtained. All four coils lie inside a brass tube, and by turning a screw, at one turn coils 1 and 3, at another, 2 and 4 are brought opposite the opening. Langley's results appear to be five times more delicate than those of the author. This is due to Langley's galvano-

meter being twenty times more sensitive.—*Nature,* July 26, 1888, p. 311. J. T.

4. *Ether Calorimeter.*—Professor NEESEN, at a meeting of the Physical Society of Berlin, described an ether calorimeter which presents certain advantages over an ice calorimeter. It consists of a tube for the reception of the object. This tube is surrounded with a layer of lamp wick which dips into ether at its lower end. From the side of the outer vessel a tube passes with appropriate bending to a horizontal capillary tube containing as index some ether, and by a parallel capilliary tube to a second and similar calorimeter. After the index has been adjusted, its movement, as resulting from the vaporization of ether due to the warm object, indicates how much heat has been given up to the wick saturated with ether. The sensitiveness of this calorimeter is 2000 greater than that of an ice calorimeter. Specific heats of platinum, palladium and copper, and also the heat produced by the passage of an electric spark between a metallic point and a mass of mercury in the tube of the calorimeter were obtained. Extremely small masses could be examined by this apparatus. The apparatus could also be used in measurement of radiant heat. —*Nature,* July 26, 1888, p. 311. J. T.

5. *Electrolysis of Water.*—In continuation of his previous researches upon this subject, H. VON HELMHOLTZ shows the influence of occluded gases in the use of platinum electrodes, especially if the platinum had been exposed to a flame in the process of cleaning. These occluded gases continue to manifest their action for a long period. The apparatus employed in the later researches consisted of a species of Sprengel pump, in one chamber of which electrolysis could take place under varying pressures. The limit for the development of gas was between 1·64 and 1·63 volts, under a pressure of the gases amounting to 10^{mm} water.—*Ann. der Physik und Chemie,* No. 86, 1888, pp. 737–751. J. T.

II. GEOLOGY AND NATURAL HISTORY.

1. *Explosive volcanic eruption in Japan on the* 15*th of July.*—The following facts are taken from a letter of Mr. J. S. MANSFIELD, Attaché of the United States Legation in Japan, written after a visit to the region, and published in the Atlanta Constitution, excepting a few from Milne's memoir on Japan volcanoes.

The eruption took place from the principal peak of Bandai-san, and did its work with wonderful violence and despatch.

This summit is the highest of the group of hills on the north side of Lake Inawashiro. In the hills, Mr. Milne states, there are hot springs, and also on the flanks of Bandai-san; and "these apparently indicate the volcanic nature of the region." He ascended it in three and one-half hours, and found the slope of the upper part 35°, and the summit, a sharp peak, 5100 feet above tide-level, but without signs of action. "From the hot springs,

the scoriaceous appearance of the old lava-streams, and the tradition in the neighborhood that it was once in a state of eruption," this mountain is classed by Mr. Milne in the group of still active volcanoes (p. 113).

Indications of approaching activity occurred on the 13th, when there were the rumblings of light earthquakes. On the 15th, at about 7 A. M., there was a more arousing disturbance, which was followed by three earthquake shocks at intervals of ten minutes; then occurred a loud explosion the noise of which the people compared to the report of thousands of cannon discharged simultaneously, accompanied by another terrible earthquake shock. A "thick, black smoke" rose from the peak, and the region for eight or ten miles around became enveloped in midnight darkness from a shower of fine black ashes and suffocating sulphurous dust with stones. At 10 o'clock A. M. the eruption was at its height, and at 4 P. M. it was finished. The number of people who lost their lives, according to the official statement, was 518, besides 41 in the hospital; but this was partly by drowning owing to the sudden rise of the river Okawa. The flowing stream at the eruption was a stream of mud. The mud and fine ashes covered the eastern and the northern side of the mountain, running down in streams each half a mile wide to a distance of four or five miles. Places one to two miles from the foot of the mountain suffered little from the ashes or mud-streams. There was no flow of lava. The eruption in all its features was of the explosive kind, much like those of Krakatoa and Tarawera. J. D. D.

2. *American Geological Society.*—During the recent meeting of the American Association at Cleveland, the question of establishing an American Geological Society, with reference to which a committee had been appointed some years before, was favorably discussed, and a provisional constitution and by-laws were accepted. Professor Alexander Winchell was chairman of the meeting, and was continued as chairman of the committee of organization. It was agreed that the Society should meet for organization as soon as one hundred names were pledged. A society for the free discussion of the many questions which investigations in various parts of the land are constantly bringing forward, for the sake of mutual increase in knowledge, and for the comparison and correction of views, is more needed in geology than in any other branch of science. It cannot fail to be of great service to the science and the members of the society.

Further information may be obtained of Professor J. J. Stevenson, University of the City of New York, Washington Square, New York City, Secretary of the Committee. It is proposed to hold the first meeting within the week before the first of January.

3. *Cambrian Trilobites from L'Iglesiente in Sardinia;* by Prof. GIUSEPPE MENEGHINI (from vol. iii, of the Memoirs of the R. Comitato Geologico d'Italia. Firenze, 1888.)—Prof. Meneghini describes in this paper, from the *lower beds* 2 species of *Olenus*, 3 of *Paradoxides*, 5 of *Conocephalites*, besides mentioning

and figuring other undetermined species of each of these genera except Paradoxides and of *Anomocare;* and from the *upper beds*, 2 species of *Anomocare*, 1 of *Platypeltis* and 1 of *Psilocephalus*, besides undetermined species of *Conocoryphe* and *Liostracus*. All are new species.

4. *A Bibliography of the Foraminifera, Recent and Fossil*, from 1565 to 1888, with notes explanatory of some of the rare and little known publications; by CHARLES DAVIS SHERBURN, F.G.S. 152 pp. 8vo. London, 1888. (Dulau & Co., Soho Square).—Mr. Sherborn's Bibliography has been prepared evidently with great care and thoroughness. A letter of his published in Nature for April 19th states that he was prompted to prepare the work by the imperfections in the bibliography published by the Minnesota Natural History Survey.

5. *Decomposition of Native Iron Sulphides.*—Prof. A. A. JULIEN has investigated with much care (Ann. N. Y. Acad. Sci., iv, 1888) the minerals pyrite, marcasite and pyrrhotite with reference to their decomposibility in order to ascertain the cause of the difference in durability of some of the kinds of so-called pyrites. He reaches the conclusion that pyrite usually contains more or less marcasite, and as marcasite is the more oxidizable sulphide, the more marcasite present the more ready it is to oxidize. Pyrrhotite may be present in pyrite with the same result, but this is not common. The mixture of marcasite and pyrite, he observes, may be due either to mixture during crystallization or to alteration, and the alteration may go so far as to produce a paramorph. A light color in pyrite shading toward white, or specific gravity below 4·99 is evidence that marcasite is probably present, even when the pyrite is well crystallized; but "little danger from decomposition may be expected down to a specific gravity 4·97, equivalent to at least 80 per cent of pyrite."

6. *Rock-Forming Minerals;* by FRANK RUTLEY, F.G.S. 252 pp. 8vo. London, 1888 (Thomas Murby).—This is a useful book, giving in systematic form and with considerable fullness, the methods of petrographical research and particularly the characters of the minerals which enter into the composition of rocks. There is no lack of books of this character, but for the most part they are in German, and the English-speaking student has been thus at a disadvantage; this new work will consequently find a welcome at once.

7. *Uraninite* (Communicated).—Dr. W. F. HILLEBRAND, who has been working for some time past on the composition of uraninite, states that he finds in the Middletown mineral 10 per cent of ThO_2, in that from Branchville 7 per cent, and in that from Colorado, 7 per cent of ZrO_2 without ThO_2. The detailed discussion of the subject will be published later.

8. *Heather in Townsend, Mass.*—Mrs. RALPH BALL, of Townsend Centre, Middlesex County, reported, this summer, a new station for *Calluna vulgaris*. The locality, which is only a few miles from the New Hampshire line, has just been visited by Dr.

Sereno Watson, Mr. Walter Deane and the present writer. The plant grows in large patches in a pasture on the south side of the railroad, half a mile from West Townsend. Strong plants of the common variety of the species are found in an area of about two acres of open field, here and there forming compact beds some of which are more than eighty feet in circumference. In the adjoining woods only a single plant was detected, but a more protracted search would probably have brought others to light. The soil where the plants are most thrifty consists of sand mixed with gravel, and contains a fair amount of vegetable mould. The ground has a gentle slope with considerable inequalities, and, in a few places, is sufficiently wet to support a good growth of cranberries, but the heather is abundant in the drier as well as the moister parts. The plant is thoroughly established, and appears as much a part of the indigenous vegetation as any of the native plants with which it grows. From its proximity to the Tewksbury and Andover localities, which are perhaps twenty-five or thirty miles in an easterly direction, this station promised to be of special interest as bearing on the indigenous character of the heather found elsewhere in this country. Inquiry reveals the unwelcome fact that the Townsend heather comes from seeds which were sown there not very far from twenty years ago. Mr. Eldridge Saunders, to whom the field belongs, states that certain relatives, on their return from a visit to Europe, brought back some plants of heather. From these plants a quantity of seed was obtained and sown in the pasture above described. The relatives do not recollect very distinctly the method of sowing the seeds, but it is remembered that there was some discussion, at the time, as to the best place for planting, and the decision was finally made to try the plants in this wet pasture rather than in the drier soil near the house. The date of sowing cannot be fixed more nearly than by the fact that the journey to Europe was made at some time during the progress of the Franco-Prussian war—that is, after the summer of 1870. The history of this station for Calluna throws much doubt on the native character of the plants at the other reported localities. It also indicates how readily this plant can be established even in our comparatively dry climate. It would appear to be possible to cultivate heather as a decorative plant on any of our moist sandy slopes. G. L. G.

9. *Insect Life.*—A periodical bulletin with the title *Insect Life* has been commenced at Washington by the Department of Agriculture. It is devoted, as the title page of the first number states (dated July, 1888), to the economy and life-habits of insects especially in their relations to agriculture, and is edited by the Entomologist and his assistants, with the sanction of the Commissioner of Agriculture. The journal will enable the department to give early publication to the facts and communications that are constantly reaching it from various directions, and render it of greater value to the public. The writer reads in it, with some interest the fact that "the Hessian Fly, *Cecidomyia destructor*,

has reached New Zealand," the March number of the New Zealand Farmer reporting it from four different farms in one of the districts, as it calls to mind his finding its pupæ in the wheat fields of Minorca, Toulon and Naples in the year 1834, as reported in this Journal* by Mr. E. C. Herrick to whom specimens of the pupæ and insects were sent at the time. I may add that I was led to make the search for the pupæ by my friend Mr. Herrick, who had become much interested in its history. It would now be interesting to learn whether the fly reached New Zealand through America or in the opposite direction. J. D. D.

10. *The Fauna of British India*, including Ceylon and Burma. Part I, Mammalia, by W. T. Blanford, F.R.S. Published under the authority of the Secretary of State for India in council. 250 pp. 8vo. London, 1888. (Taylor & Francis.) This is a carefully prepared systematic treatise on the Mammals of India. The part here published closes with the Insectivora, leaving the Ungulata, Rodentia, Edentata, Chiroptera, Cetacea, and Sirenia for another part. Several of the species are illustrated by excellent figures.

11. *Entomology for Beginners, for the use of Young Folks, Fruit Growers, Farmers and Gardeners;* by A. S. PACKARD, Ph.D. 366 pp. 12mo. New York, 1888. (Henry Holt & Co.) —Prof. Packard's Entomology for Beginners is made very attractive, by its copious and beautiful figures illustrating various insects of the several orders, and also their habits, structure, metamorphosis, nest-making, constructive and destructive work. The work is also a practical one for the young entomologist, giving him directions for collecting, rearing, preserving, dissecting and mounting insects, and also for making microscopic sections of various kinds and for their preservation. It closes with a long list of works on Entomology and its several departments, besides a full glossary. The style of publication adds to the attractiveness of the volume.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *American Association for the Advancement of Science.*— The meeting of this Association opened at Cleveland on the 15th of August, under the presidency of Major Powell, Director of the U. S. Geological Survey. The officers elected for the coming year are the following :—*President:* T. C. MENDENHALL. *Vice-Presidents:* Mathematics and Astronomy, R. S. WOODWARD; Physics, H. S. CARHART, of Ann Arbor, Mich.; Chemistry, WM. L. DUDLEY, of Nashville, Tenn.; Mechanical Science and Engineering, A. BEARDSLEY, of Swarthmore, Pa.; Geology and Geography, Dr. C. A. WHITE; Biology, Prof. G. L. GOODALE; Anthropology, G. MALLORY, of Washington, D. C.; Economic Science and Statistics, C. S. HILL, of Washington. *Permanent*

* Vol. xli, 154, 1841.

Secretary: F. W. Putnam. *General Secretary:* C. L. Mees, of Terre Haute, Ind.

The next meeting of the Association will be held in Toronto, on the last Wednesday in August.

The retiring president, Prof. S. P. LANGLEY, delivered an address on a History of a Scientific Doctrine; Major POWELL, the President of the meeting, on Competition as a factor in Human Progress; C. E. MONROE, Vice-President of the Chemical Section, on Some Phases in the progress of Chemical Science; Prof. G. H. COOK, Vice-President of the Geological Section, on The International Geological Congress and our part in it as American geologists; Prof. C. C. ABBOTT, of the Section on Anthropology, on the Evidences of the Antiquity of Man in Eastern North America; Prof. ORMOND STONE, of the Section of Mathematics and Astronomy, on the Motions of the Solar System; Prof. A. A. MICHELSON, of the Physical Section, "A Plea for Light Waves."

The following is a list of the papers accepted for reading:—

SECTION A.—*Mathematics.*

E. W. HYDE: The directional theory of Screws.—Considerations on the fundamental idea of quaternions.

H. M. PARKHURST: Obliteration from illumination in stellar photometry.

E. D. PRESTON: Deflections of the plumb line, and variations of gravity in the Hawaiian Islands.

R. S. WOODWARD: Laws of frequency of errors of interpolated logarithms.

J. W. HOUGH: On a new method of construction of equatorial domes.

JAMES MCMAHON: A method of representing the imaginary elements of a geometric figure and of using them in construction.

S. C. CHANDLER: On a new catalogue of variable stars.

H. M. PAUL: A new short period variable in *Antlia.*

WILLIAM HARKNESS: On the value of the solar parallax deduced from the American photographs of the last transit of Venus.

G. C. COMSTOCK: A desideratum in the American Ephemeris.

D P. TODD: Fusiyama, Japan, as a site for a mountain observatory.

ASAPH HALL: On the supposed canals on the surface of the planet Mars.

WILLIAM HOOVER: Preliminary elements of the orbit of comet 1886, IX.

C. A. WALDO: Note on the mathematics of the seismoscope.

H. B. NEWSON: On some old and new theorems in Solid Geometry.

LEWIS BOSS: Orbit of Brooks's comet—1888, C.

IRVING STRINGHAM: On the measure of inclination of two planes in space of four dimensions.

F. BOAS: On census maps.

SECTION B.—*Physics.*

W. LECONTE STEVENS: On the quality of musical sounds.

W. A. ROGERS: On the radiation of heat between metals by induction and conduction, with numerical results for steel and brass.—On the terms mass and weight.

E. P. HOWLAND: On the best methods of making instantaneous photographs.—Description of a new and improved dissolver for the lantern.

C. A. OLIVER: Note upon retinal photography.

R. S. WOODWARD: On the emissivity of a metallic bar cooling or heating in air.

T. C. MENDENHALL: On dynamical units.—Effect of added term of the equation of the quadrant electrometer on its deflection curves.

C. J. H. WOODBURY: Protection of watches against magnetism.

F. P. Whitman: Photographic experiments on the color of the sky.

J. W. Moore: Galvanometer for the vertical lantern.—Two strokes of lightning.

A. A. Michelson and E. W. Morley: Description of apparatus for making a light wave the standard of length.

R. B. Fulton: Novel form of electro-magnetic telephone.

E. L. Nichols and W. S. Franklin: Experiment on the direction and velocity of the electric current.—Spectro-photometric comparison of sources of artificial illumination.

W. H. Bristol: New pressure indicator.—New self-registering thermometer.—New self-registering barometer.

E. Merritt: Efficiency of incandescent lamps.

J. B. Webb: Floating dynamometer.—Impact in the injector.—Overhauling in a mechanical power.

M. A. Veeder. Causes of sudden variation of atmospheric pressure.

Section C.—*Chemistry.*

R. B. Warder: Co-efficients of volatility for aqueous chlorhydric acid.

W. A. Noyes: On a new method for the determination of the atomic weight of oxygen.—On the oxidation of nitro-p-xylene with potassium ferrocyanide.

F. P. Dewey: Hampe's method of determining cuprous oxide in metallic copper.

F. B. Power: On the constituents of wintergreen leaves.

S. B. Newberry: Propylidene di-ethyl and di-methyl ethers.—The safety of commercial kerosene oils.

Thomas Taylor: A new vegetable dye.—The crystals of butter and fat.

E. H. S. Bailey: On the presence and significance of ammonia in potable waters.

C. F. Maybery and H. H. Daw: Composition of salt brines in Northern Ohio.

Wm. P. Mason: Fatal poisoning by carbon monoxide.

Albert W. Smith: Lake Erie water at Cleveland, Ohio.

F. H. Morgan: Some notes on progress in chemical methods of water analysis, with especial reference to ammonia process.—Note upon iodine as a reagent in the analysis of drinking water.—Note on the final product of the action of concentrated sulphuric acid on sugar.

W. L. Dudley: Some modifications of the methods of organic analysis by combustion.

W. O. Atwater: The chemistry of fish.—The quantities of nitrogen in protean compounds.

Section D.—*Mechanical Science and Engineering.*

J. E. Denton: On the possibility of identifying dry or saturated steam by visual observation of a jet of such steam flowing into the atmosphere.—Relative economy of high speed engines of less than 50 h. p., using steam by expansion and throttling respectively.—On the influence of moisture in steam upon the steam consumption per h. p. of engines of less than 50 h. p.

Wolfred Nelson: The Panama canal as it is.

R. S. Peary: Recent Nicaragua ship canal surveys.

D. S. Jacobus: Effect of friction at the connecting rod bearings on the forces transmitted.—General solution of the transmission of force in a steam engine including the action of friction, acceleration and gravity.

R. H. Thurston: The second law of thermodynamics.

W. J. Keep, C. F. Mabery and L. D. Vorce: The influence of aluminum upon cast iron.

O. H. Landreth: The economical production of charcoal for blast furnace purposes.

Section E.—*Geology and Geography.*

G. C. Broadhead: The geological history of the Ozark uplift.

F. W. Simonds: The Archimedes limestones and associated rocks in Northwestern Arkansas.

Alexander Winchell: Systematic results of a field study of the Archæan rocks of the northwest.

H. S. WILLIAMS: The use of fossils in determining the age of geologic terranes.

J. E. TODD: The terraces of Missouri.—Extra morainic striæ in the Missouri valley.—Evidence that Lake Cheyenne continued till the ice age.

G. F. WRIGHT: Boundary of the glaciated area in Dakota.

A. S. TIFFANY: Evidences that the Mohawk river, at a very remote period, changed its channel of drainage.

F. H. KNOWLTON: The fossil wood and lignites of the Potomac formation.

L. F. WARD: The paleontological history of the genus Platonus.—Remarks on an undescribed vegetable organism from the Fort Union group, Montana.

C. A. WHITE: The Cretaceous deposits of North America.

R. T. HILL: The occurrence of chalk in the North American Cretaceous.

J. S. NEWBERRY: The Cleveland Shale and its fossil fishes.—The oil field of Colorado.

EDWARD ORTON: Discovery of sporocarps containing protosalvinia huroniensis in the Ohio shale.—The recently discovered sources of oil and gas in Ohio, Indiana and Kentucky.

H. P. CUSHING: A new gas well at Cleveland.—Geology of Cleveland.

J. F. JAMES: The ancient channel of the Ohio at Cincinnati.—Ivorydale well in Mill Creek valley.

P. MAX FASHAY: Notes on the preglacial drainage of Western Pennsylvania.

J. W. SPENCER: Discovery of the ancient St. Lawrence River.—Origin of the basins of the great lakes.—Establishment and dismemberment of Lake Warren.—Discovery of the outlet of the Huron-Michigan-Superior lakes to Lake Ontario by the Trent valley.—Erie the youngest of all the lakes.

T. C. MENDENHALL: On the intensity of earthquakes with approximate calculations of the energy involved.

J. F. KEMP: On the trap dikes of Kennebunkport, Maine.

N. H. WINCHELL: Some thoughts on eruptive rocks with special reference to those of Minnesota.

C. W. HALL: The distribution of the granites of the Northwestern States, and their general lithologic characters.—Some physiographic notes on Northeastern Minnesota.

J. C. BRANNER: The geologic age of the crystalline rocks of Arkansas.—The age and correlation of the Mesozoic rocks of the Sergipe-Alagoas basin of Brazil.

J. C. BRANNER and R. N. BRACKETT: The Peridotites of Pike County, Arkansas.

A. WANNER: The discovery of fossil tracks in the Triassic of York County, Penn.

R. HAY: Recent discovery of rock salt in Kansas.

FRANK LEVERETT: On the occurrence of the forest bed beneath intra-morainic drift.

J. T. B. IVES: On a new method of constructing geologic maps.

R. OWEN: Probable derivation of the terrestrial spheroid from the rhombic dodecahedron.—Additional facts respecting the law governing the distribution in space of seismism.

SECTION F.—*Biology.*

N. S. BRITTON: A plea for uniformity in biological nomenclature.

THOS. MEEHAN: A study of the Hydrangea as to the objects of cross-fertilization.—Some new facts in the life history of Yucca and the Yucca moth.—On the cause and significance of dichogamy in flowers.—Adaptation in the honeysuckle and insect visitors.

C. L. STURTEVANT: A phase of evolution.

JOS. SCHRENK: Notes on the inflorescence of Callitriche.

A. N. PRENTISS: Hygroscopic movements in the cone scales of Abietineæ.

J. B. SMITH: Sexual characters of the species of the Coleopterous genus Lachnosterna.

O. P. HAY: On the structure of the skull of the larva of Amphiuma.—A supposed new species of Branchipus from Indiana.

W. EDGAR TAYLOR: Color variations of Nebraska flying squirrels.

T. B. STOWELL: The muscles of the soft palate in the domestic cat.

E. P. HOWLAND: Some new experiments in producing anæsthesia with nitrous oxide and air, and nitrous oxide and oxygen in condensed air chambers.

W. J. BEAL: Comparisons of the flora of Eastern and Western Michigan in the latitude of 44° 40′.—Observations on the succession of forests in Northern Michigan.

D. H. CAMPBELL: The systematic position of the Rhizocarpeæ.

B. D. HALSTEAD: Pollen germination and pollen measurements.

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2. *India in* 1887, *as seen by Robert Wallace*, Prof. Agric. and Rural Econ., Univ. Edinburgh. 264 pp. 8vo, with numerous collotype and other plates. Edinburgh, 1888. (Oliver & Boyd, Edinburgh). This volume by Professor Wallace is one of great interest as regards the agriculture and forestry of India, and its

breeds of cattle, its stock raising, the extent of variations in breeds, cattle diseases, etc. Its photograph plates (collotypes) are 45 in number and are mostly devoted to the various breeds of cattle of different parts of India. Besides these there are other plates containing sketches of grasses and two colored maps illustrating the orographic features and political divisions of India. Prof. Wallace, in the course of his descriptions of the cattle of India, states the remarkable fact that "however white the hair may be, all but a very small percentage have jet-black skins underneath." An animal with a white skin is considered to be weakly. "There is little doubt," he says, "that the black skin has much to do with the ability of Indian cattle to work in the sun without suffering as light-skinned cattle do." White-skinned cattle are liable to have their skins sunburnt, and sometimes affected by an eruption. So also "the skins of sheep, pigs, buffaloes and horses under domestication in India are usually black or dark." The best breeds of sheep have a white skin over the body, it being protected by the thick wool, but the head, in that case, is frequently black. The black color causes the skin to absorb more heat than the white skin, but also to give off more heat, and in addition the temperature is diminished much by evaporation from the skin. The natives of India *appear* to perspire much less than Europeans, but because more of the perspiration passes from them in the form of vapor.

3. *Eclectic Physical Geography*; by RUSSELL HINMAN. 382 pp. 12mo, with numerous colored maps and other illustrations. Cincinnati, 1888. (Van Antwerp & Bragg).—This volume, although small, gives an excellent review of the different topics embraced under the head of Physical Geography. The definitions and explanations are clear and well presented, though sometimes too brief; the illustrations are very numerous and of superior quality, and the presswork and general style of the volume of high credit to the printers and publishers.

Index to the Literature of the Spectroscope by A. Tuckerman, Ph.D. 424 pp. 8vo. 1888. Smithsonian Institution, No. 658. Washington, D. C.

The Constants of Nature. Part I, A table of specific gravity for Solids and Liquids. New edition revised and enlarged. By F. W. Clarke, Chief Chemist U. S. Geological Survey. 410 pp. 8vo. 1888. Smithsonian Institution, No. 659. Washington, D. C.

Transactions of the Connecticut Academy of Arts and Sciences. Vol. VII, Part 2. pp. 261 to 464, closing the volume. New Haven, Conn., 1888. The pages are occupied by six chemico-physiological papers covering 180 pages, by Prof. R. H. Chittenden, and M. T. Hutchinson, Prof. C. and J. A. Blake, Prof. C. and H. H. Whitehouse, Prof. C. and P. R. Bolton, Prof. C. and H. M. Painter, and Prof. C. and G. W. Cummins. These papers are followed by one of 16 pages on New England Spiders of the Family Ciniflonidæ, by J. H. Emerton, illustrated by three plates—9 to 11.

OBITUARY.

SILAS STEARNS.—Mr. Silas Stearns, ichthyologist, and an efficient agent of the United States Fish Commission, died in Asheville, N. C., August 2, 1888. He was born at Bath, Maine, on the 13th of May, 1859, and in the schools of that place received his early education.

In 1875 he went to Pensacola, Florida, and there became associated with his brother-in-law, Mr. A. F. Warren, in business. But he began there also his study of fishes and other species of the waters; and through his various excursions he became familiar with all the ins and outs of the coast from Pensacola to Key West. In 1878 he visited the Smithsonian Institution, and by his thorough and exact knowledge with regard to the fishes of the Gulf, their habits and their economic value, he attracted special attention from Professor Baird, Mr. Goode and others. The following year he spent at Waterville, Me., in classical studies at the Academy, for the benefit they might be to him as regards scientific nomenclature—showing thereby that earnestness and energy of character which was an assurance of future success and honor. Failing health compelled him to return to Florida, and in 1880 he became a special agent of the U. S. Fish Commission, and also of the U. S. Census Bureau, in charge of investigations of the marine industries of the Gulf of Mexico. His reports show that his work was performed with accuracy and fidelity. From this time his contributions to the Fish Commission became numerous and large, as the Annual Reports of the Commission show. Upwards of fifty new species of fishes were discovered by him or through his help, embracing much of what is known of the deep-water fishes of the Gulf; and four of the species—of the genera Lutjanus, Scorpæna, Blennius and Prionotus—bear his name. During these years in Florida naturalists investigating the fauna of the Gulf of Mexico have had his untiring aid, and most of them were guests under his roof and sailed in his boats on their collecting tours. They found in him a generous and most estimable friend.

In 1886 Mr. Stearns was married to Miss Hays, of St. George, Maine. He leaves no children. DAVID STARR JORDAN.

R. CLAUSIUS.—Professor Clausius, the great mathematician and physicist, died on the 24th of August in his 67th year. His death takes away one of the world's deepest thinkers, the value of whose contributions to physical science cannot be overestimated. The present development of thermodynamics is due to a large extent to his labors, in which field his investigations were numerous and profound. His work extended also over other branches of mathematical physics. His published papers number considerably over a hundred. He was also a most successful teacher and since 1869 has been a center of attraction at the University of Bonn.

RICHARD A. PROCTOR.—Professor Proctor, the English astronomer, died on the 12th September in his 52d year. He has been best known as a lecturer and popular writer upon astronomical and kindred subjects.

PHILIP HENRY GOSSE, F.R.S., the eminent English zoologist, died on the 27th of August in his seventy-ninth year.

M. HENRI DEBRAY, the French chemist, died on the 19th of July, in his sixty-first year.

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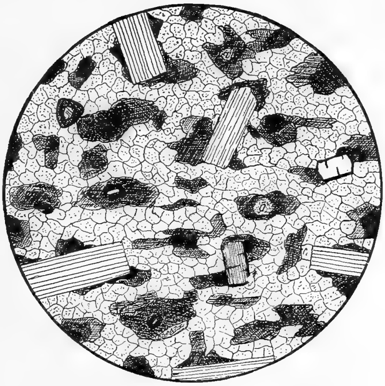

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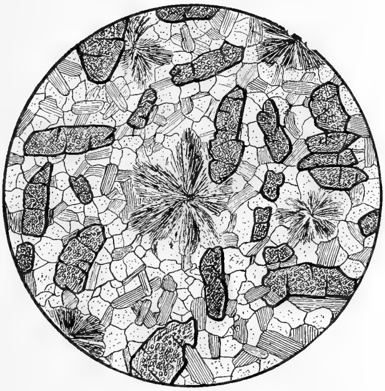

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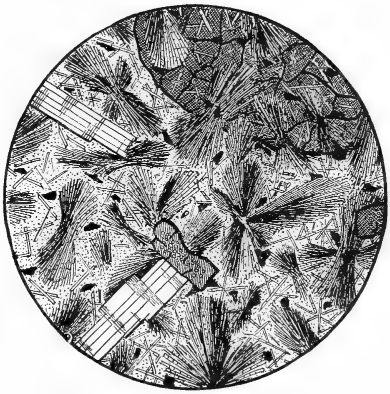

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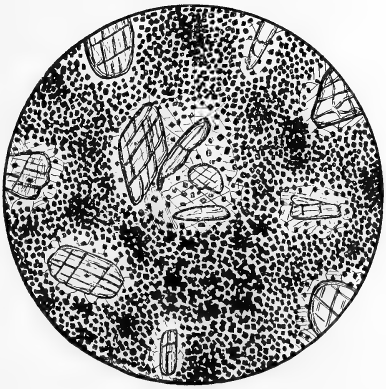

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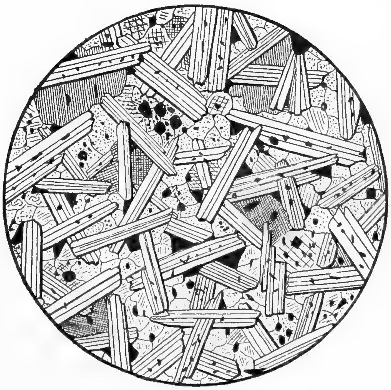

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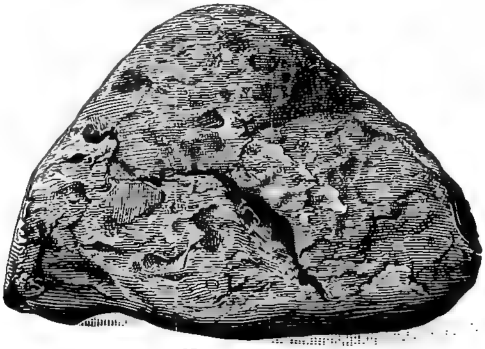

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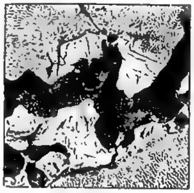

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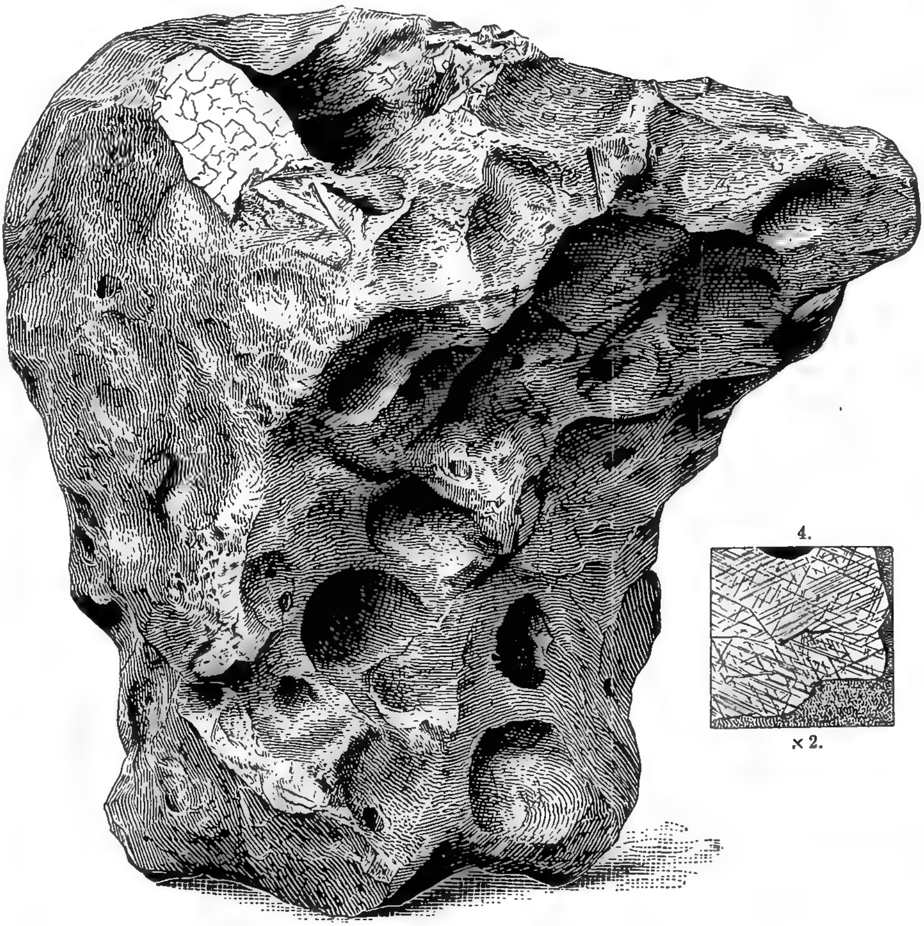

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U. S. Geological Survey.

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[THIRD SERIES.]

Art. XXXIII.—*On the Deflection of the Plumb-line and Variations of Gravity in the Hawaiian Islands;* by E. D. Preston, Sub-Assistant, U. S. Coast and Geodetic Survey.

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On the return of the Solar Eclipse Expedition from the South Seas, in 1883, two of the party stopped in the Sandwich Islands for the purpose of determining the force of gravity. An old pendulum station on the island of Maui, occupied by DeFreycinet in 1819, was the point chosen. While there the latitude of the place was determined with precision, by the method of equal zenith distances. This latitude was carried back by triangulation to Honolulu by Professor Alexander, the Surveyor-General of the islands. It was there compared with the local astronomical latitude as given by Captain Tupman, of the British Transit of Venus Expedition of 1874. Their comparison revealed a discrepancy,—quite incompatible with the accuracy of the work,—as shown either by the star observations at the terminal points, or by the triangulation connecting them. This seemed to prove, as indeed had long been suspected by Professor Alexander, that there were unusual plumb-line deflections. Both the excess of matter in the high mountain masses above, and the defect of matter in the deep sea below, would indicate this.

In view of the importance of the determination of these deflections in the survey of the islands, as well as the general scientific interest in the subject, the Hawaiian government was led to ask the coöperation of the United States in the work of determining with precision a number of astronomical latitudes. Accordingly, in December, 1886, with the sanction of the Honorable Secretary of the Treasury, the Superintendent of the Coast and Geodetic Survey loaned the necessary instruments, and granted one of the members of the service a leave of absence long enough to make the observations On the part of the Hawaiian Survey, Messrs. F. S. Dodge and W. A. Wall assisted in the gravity observations. Mr. Wall was permanently attached to the party and recorded all the latitude work.

The credit of the work, therefore, belongs in part to both governments. The Island Survey bore all the expenses, and selected the stations; the Coast and Geodetic Survey loaned the instruments, furnished the observer, and is making the computations.

Later it was thought desirable to supplement the latitude work, by the determination of the force of gravity on the top of one of the mountains, and at the sea-level. This would give a check on the deflections determined at the foot of the mountain, by means of the zenith telescope. For, whether there exist great caverns under the visible surface or not, the pendulum will give us a value for the mean density of the whole mass. Then, knowing the volume and density, it is a simple arithmetical process to find its influence on the plumb-line suspended at a given distance from it. The liberality of the Hawaiian government can only be commended when we find it devoting time and money to the solution of scientific questions in which the rest of the world is quite as much interested.

The scope of the work was as follows: Fourteen latitude stations were to be established on the four principal islands of the group, viz: Kauai, Oahu, Maui and Hawaii. These were distributed in such a manner as to bring out the deflections of the plumb-line; being in general north and south of the high mountains. At each one of these stations it was proposed to observe thirty-three pairs of stars on three successive nights; which would bring the probable error of the resulting latitude below one-tenth of a second of arc.

Practically, however, this plan could not be rigidly adhered to. At all the windward stations the weather was very unfavorable for astronomical observations. At Kohala the wind was always too strong to allow us to pitch a tent in which to live. An old sugar storehouse, long since abandoned, served instead. At Hilo, where the rain-fall is sixteen feet in one

year—and this all falls during the time the trades blow—only one good night's observation could be obtained in a month's stay. At Ka Lae the station was eight miles from the water supply; the road leading part of the way over the rough lava known as the "aa." All these circumstances made it necessary to make the best possible use of good weather, when so favored, and not unfrequently over one hundred pairs of stars were selected for observation on a single night. The greatest number obtained, however, was seventy-five, these being taken at Kaupo in less than eight hours' observing. Satisfactory work was done, allowing only one minute and a half between pairs, and thirty seconds between stars of the same pair. In this time the micrometer was read and the instrument revolved 180° in azimuth. The whole number of observations was about 1500, being on the average more than one hundred for each station.

The mean places of these stars are being deduced by Mr. Henry Farquhar, at the Coast Survey office, and will be very reliable—about twenty of the best modern catalogues being consulted. Many of the stations, however, being nearly in the same latitude, pairs of stars occur which are common to several places; so that the difference of latitude of these stations is independent of any error in the declinations.

For the gravity work two pendulums were supplied by the Coast and Geodetic Survey. They were of the reversible pattern one measuring a meter between the knife edges and the other a yard. They were to be swung on top of one of the mountains, at the sea level, and at Honolulu, to connect the work with that done in 1883 by the U. S. Eclipse Expedition.

The mountain chosen was Haleakala on the island of Maui. It rises slightly over ten thousand feet above the sea and has on its summit one of the largest extinct craters of the world:—the crater itself being half a mile deep and twenty miles in circumference. At the southwestern corner of this gigantic pit and within fifty feet of its perpendicular walls the instruments were set up and the force of gravity determined.

The Yard Pendulum is common to both the determinations of 1883 and those of 1887.

The scheme for conducting the observations was identical for each station and was strictly adhered to as far as the circumstances would permit. The pendulum was swung day and night without interruption from the beginning to the end of the observations. Stars were first obtained for time, and the pendulum was started at the time of reversing the telescope. This being the mean epoch of the star observations, the oscillations were thus referred directly to the stars without depending on the rate of the chronometer. The same stars when

possible being observed on successive nights, the errors in right ascension were also in a great measure eliminated.

Six swings were made with the heavy end down. The pendulum was then revolved 180° around its longitudinal axis, and six more swings were made. It was then reversed end for end, and the same number of swings made with the heavy end up. This completed the work with one pendulum. The other was observed similarly, and stars were obtained every night—the mean epoch, as usual, being at the time of beginning a new series of oscillations with the pendulum.

The time was determined with a meridian telescope—the transits of stars as well as those for the pendulum being registered on a Fauth chronograph. Two small cells supplied the electric circuit in which were placed the chronograph, a sidereal chronometer, and two observing keys. The chronometer broke the circuit every two seconds.

The knife-edge plane of the pendulum head was made level. The precaution was taken to hang a weight equal to the pendulum on the projecting arm during the operation, to see that no appreciable deflection was caused. A similar test was made for the whole support. The barometers were carefully compared with Signal Service standards. The thermometers which were made by Baudin, and can be read to hundredths of a degree centigrade, had their corrections determined in this country both before and after the expedition. The zero point of one of them was determined in the islands, and they were compared on the mountain immediately after the experiments were concluded.

Although Haleakala is in the tropics and was occupied in midsummer, we found great ranges of temperature on the summit. Ice was formed at night to the thickness of quarter of an inch. The clouds do not usually come within several thousand feet of the top, which gave us a clear atmosphere for the astronomical part of the work. Indeed many stars were observed before sundown with a telescope of 2½ inches aperture and magnifying power of 70. One low star for azimuth and four high ones for time were taken before reversing the telescope. The same program after reversal, completed the evening's observations—the usual level readings being made as often as possible during the work.

It was found impracticable to carry the pendulum stand to the summit; but a better natural support was found, and the pendulums were swung in a cavity between two rocks. This opening was closed behind by masonry laid in cement, and before by tarpaulins, blankets, and dry masonry. The room thus formed was about nine feet high by 3½ feet in diameter and gave a quite uniform temperature.

These conditions were much more favorable than those that would have resulted from carrying out the first conceived plan of taking a stand to the top and swinging in a double tent. No more perfect support could be had than a two inch plank imbedded in solid masonry, and a cavern protected on three sides by twenty feet of rock gives exceptionally good temperature conditions. The support in its essential features was the same for all three stations.

Three thermometers placed near the top, middle, and bottom of the room were used throughout the work. The one below was attached to a brass rod, and the rod and thermometer were enclosed in tin foil--thus insuring as far as possible the same temperature for both. The brass rod and the pendulum being of the same metal, the lower thermometer was supposed to indicate the true temperature of the pendulum at its lower end. This thermometer was read continuously throughout the swing. The middle and upper ones were only read when it was necessary to enter the room to start the pendulum. By this means we get a very accurate idea of what the real temperature is, throughout the whole length of the bar. At one station a fourth thermometer was employed which gave the temperature of the air in the immediate neighborhood of the attached thermometer and rod. When these means are employed it is hard to believe that an error in the mean temperature of the whole pendulum can be made as great as one-tenth of one degree. The influence of such an error is quite within the general range of errors of observation, or accidental errors beyond our control.

The oscillations were observed from the transit tent twelve feet distant by means of a small theodolite. A window of plate glass was built in the wall of the pendulum house, and through it the observations of transits, amplitude of arc, and lower thermometer were made.

Each swing with heavy end down was made to consist of 15000 oscillations, beginning with an amplitude of $\frac{1}{50}$ of the radius. The instant marking the beginning of the swing was determined by forty transits across the vertical wire of the telescope. The probable error of the mean of this number of transits is considerably less than one hundredth of a second. After the pendulum had swung for four or five thousand oscillations, a few additional transits were taken in order that there might be no mistake in the whole number of oscillations made. At the end of every hour and a half is quite often enough to take the intermediate transits, because the uncertainty in the determination of one oscillation, does not, in this time, accumulate to be more than half a second at most; and inasmuch as transits always begin with the pendulum moving in the same direc-

tion, we know that the whole number of oscillations is even. Hence the uncertainty of half a second throws no doubt on the number made. However, if the variations in temperature are excessive, it may be necessary to take this into account when the intervals are long; for example, one degree centigrade changes the time of oscillation by one hundred thousandth part of a second; therefore an interval of 15000 oscillations, in which there was a change of say 5°, would be different from the normal period by about $\frac{3}{4}$ of a second; and this with the uncertainties arising from the other varying conditions, would make it extremely doubtful, how many oscillations were actually observed. But if intermediate transits are taken every two hours, none of the conditions can change enough to endanger the count.

The observations are reduced to similar conditions at the different stations, as regards temperature of the pendulum, pressure of the atmosphere, amplitude of oscillation, and rate of time piece. The temperature and pressure coefficients are those employed by Professor C. S. Peirce, and which he determined experimentally for these particular pendulums. The corrections for arc were calculated by several different formulæ, all of which however gave practically the same result. That of Borda was given the preference on account of the rapidity with which the numerical computations could be performed. It supposes that the arcs decrease in a geometrical ratio, while the time increases in an arithmetical one. Peirce's formula assumes that the differential coefficient of the arc, with reference to the time as the independent variable, may be expressed in terms of the ascending powers of the arc and constants. These constants are to be determined from the curves of decrement themselves, for each set of swings; or in case no abnormal decrement occurs, mean values for the constants may be employed to correct all the swings. Weddle's rule, which finds a value for the mean square from six equidistant values, gives approximately the same result.

The varying conditions of rate, temperature, pressure, amplitude, elevation, and latitude, all influence the period by nearly the same amount, when the conditions change by certain simple units. One second per day, one degree centigrade, one inch pressure, one hundredth of the radius of amplitude, one hundred meters of elevation and ten minutes of latitude, all changing the period of a seconds pendulum by about one hundred thousandth part of itself.

In the determination of differential gravity much labor can be saved by beginning each swing at the same amplitude, and making it consist of the same number of oscillations. This makes the corrections for arc the same for all, and in the

determination of periods, it is only necessary to deal with differences instead of the whole interval.

The determination of the relative forces of gravity at the base and summit of a mountain gives sufficient data for the computation of the ratio existing between the mean density of the mountain and that of the earth.

Whether we consider the matter lying between the summit and the base, as a cone, a cylinder, or the segment of a sphere, the mathematical expression for its attraction on the upper station is approximately the same, when the horizontal dimensions of the figure are great compared with the vertical ones.

In passing from the sea level to the top of Haleakala, the time of oscillation was found to have increased by its $\frac{1}{3120}$th part, or since gravity varies inversely as the square of the time of oscillation, the decrease of gravity in passing to the summit is $\frac{1}{1560}$th part of itself.

The two stations are not in the same latitude, nor is the base station exactly at the sea level; but corrections were first applied to make them comparable as to latitude. The time of oscillation at the base station was also reduced to what it would have been at the level, of the sea.

On account of distance alone we should expect the pendulum to lose 41 seconds per day on being transported from the sea to the summit. As a matter of fact it was observed to lose only 28 seconds. Hence the mass of the mountain accelerated the pendulum by 13 seconds daily.

Employing Young's rule we arrive at a value of 43 hundredths for the ratio of the mean density of the mountain to that of the earth. Assuming the earth's density to be 5·67 the resulting density of the mountain becomes 2·4.

This is not very far from the estimated density of the rocks composing the mass, so that this determination does not indicate any large cavern under the mountain, or any very great attenuation of the matter composing it. Mountains as a general rule show a defect of gravity on their summits. But this rule has been deduced from experiments made on continental mountains, notably in Peru and India. If we admit that the surface of the sea is elevated in the vicinity of continents by the attraction of the land, mountains need not necessarily be supposed light. The great plateau of India would raise the apparent sea level immediately under it by nearly a thousand feet. This would have a very perceptible effect on the determination of the mean density of the plateau. But in the case of a mountain rising in the midst of a deep sea the surface cannot be supposed to be influenced enough to materially affect the determination of its density. In fact a plateau having an extent equal to Haleakala and a height equal to its mean height

would only elevate the apparent sea level by about ten feet. This quantity may well be neglected when we consider that the mountain is 10,000 feet high and the mean density in any case is not certain beyond two or three significant figures. Therefore we should not expect to find in mountains in the middle of the Pacific Ocean, a mean density differing very much from that indicated by the rocks found on the surface.

The value 2·4 which the pendulums both agree in showing, certainly does not depart sufficiently from that furnished by the rocks themselves, to allow us to assert that the mountain is lighter than it should be, or that there is a defect of gravity on its summit. On the contrary, the indication inclines slightly to the other side, if we accept 2·3, which has been estimated by geologists for the density of the rocks on Maui. Between 9500 and 10,000 feet there exist rocks of a comparatively great density. This being the case at such an altitude, it is most reasonable to suppose a density, great enough, to counterbalance the beds of light lava and cinder, found on many parts of the summit.

In order to have a check on the whole work, as well as to compare pendulum results with those from star observations with the zenith telescope, the following plan was adopted: Latitude stations were made on the north and south side of the island, besides an intermediate station on the summit. All these stations have been connected by triangulation, as a regular part of the Government Survey by Professor Alexander. Comparing the astronomical deflections observed on either side of the mountain, with those calculated from its volume and density as furnished by the pendulum, we shall have a test of methods as well as results and if it is found that these agree, we should feel considerable confidence in our opinions concerning the constitution of the crust.

The attraction of a mountain may be calculated in several ways. The best and most accurate, when sufficient data is at hand is that due to Dr. Hutton and is briefly this: The country around the station is divided into compartments by concentric rings and radial lines. The attraction of an element of matter depends on its density and the square of its distance from the attracted point; and we have as a result a formula which must be integrated with reference to three variables. The first integration gives us a curve in the plane of the base of the mountain: after the second we have a vertical curved surface, and with the third results the volume and attraction of one of our elementary compartments. Performing the integration then for azimuth, distance, and elevation, we have all that is necessary to compute the attraction of the mountain in the direction of the meridian of the station. Here the work

of the integral calculus ceases. But the computation of the resultant attraction of the whole mountain is further facilitated, by so choosing the distances between the circles and lines, that each compartment has a component in the direction of the meridian depending only on its height. Then the attraction of one compartment has only to be multiplied by the sum of the heights of the compartments. These conditions are realized by taking the azimuths of the radial lines, such that their sines are in arithmetical progression, and the lines themselves, such that their lengths are in geometrical progression.

The formula is,

$$\rho \int_{a_1}^{a_2} \int_{r_1}^{r_2} \int_0^h \frac{r^2 \cos \alpha \, d\alpha \, dr \, dz}{(r^2+z^2)^{\frac{3}{2}}}$$

and the final deflection is,

$$12''{\cdot}44 \frac{\rho}{\Delta} \mathrm{K}l \left[\Sigma(h) - \Sigma(\mathrm{H}) \right]$$

In calculating the deflection at Kaupo the whole island is considered in three parts, all of which lie to the north. The first is comprised between the prime vertical through the station and a semi-circumference of 10 miles radius. The second is also limited by the prime vertical and is a semi-circular ring included between radii of 10 and 26 miles. The third takes in that part lying beyond the valley, known as West Maui.

In the first part the ten radii are in arithmetical progression the common difference being one mile: in the second they have a ratio of $\frac{11}{10}$: the radius of the nth circle being $10 \times \left(\frac{11}{10}\right)^n$ or $\frac{(11)^n}{(10)^{n-1}}$ miles. In the third they are chosen arbitrarily depending on the configuration of the ground.

Radial lines are now drawn from Kaupo as a center and making angles with the meridian line whose sines have a constant difference of one-tenth. This divides the whole island into 318 compartments, the mean heights of which are determined from contour lines.* The first series of circles extends to the summit and includes the great crater. Within this limit, which makes up about $\frac{1}{4}$ the whole surface of the island, we have more than $\frac{2}{3}$ the whole attractive force. The second series goes to the valley, and practically includes all the remainder of the attraction. In computing the effect of West Maui the mountain is divided into two segments and a mean height is assumed for each: giving those parts nearest the attracted point greater weight. These heights are about

* Kindly furnished by Prof. C. H. Hitchcock.

2500 and 1500 feet and the resulting deflection is only $\frac{1}{8}$ of a second. This value compared with the total deflection caused by East Maui shows that the approximate data used for this distant part of the island are quite accurate enough. For a change of 10 miles in the distance or 10° in the azimuth only changes the deflection by a few hundredths of a second. A difference of 500 feet in elevation has about an equal influence. The distance of the center of West Maui from Kaupo is 35 miles and its mean azimuth 55°.

That part of the island lying to the south of the prime vertical is neglected. A computation of one of the compartments giving only a deflection of $''\cdot002$; besides whatever influence this land may have, is practically destroyed by the light sea lying north of the prime vertical on the east, as the two portions are nearly the same shape and size.

The sea lying to the southward will have the same influence as a volume of density equal to the difference of densities of rock and sea water. Supposing the mountain to continue to the bed of the ocean, with the same slope that it has from the summit to Kaupo, gives a cone of density of rock minus water, and volume equal to Haleakala, making up nearly all the disturbing effect. Hence we multiply the deflection found for the mountain by a factor depending on the relative densities of rock and water. Increasing the total deflection found or $17''\cdot8$ by $\frac{7}{11}$ of itself we get $29''\cdot1$ as the entire deviation of the plumb line at Kaupo. The deflection found by triangulation was $29''$. This mode of computation is the same as that employed by the Ordinance Survey in the treatment of deflections in the south of England. A shorter way and one that can be employed for an approximate value in some cases, is to consider the mountain as a paraboloid of revolution. This was done for Haleakala using the mean density furnished by the pendulum, and a value for the mass of the earth, previously employed in investigations of this kind. These data give for the deflection at Kaupo, (Ka Lae o Ka Ilio) a station on the south side of the mountain, 28 seconds, which is within one second of what was found by Prof. Alexander who carried the astronomical latitude of Haiku around the island, by triangulation to Kaupo, and there compared it with the locally determined latitude. Of course this very close agreement is only accidental because the data used are but approximate and the mountain is not a perfect paraboloid of revolution. In fact by this method the deflections cannot be known closer than a few seconds: for an uncertainty of a quarter of a mile either in fixing the radius of the mountain or in estimating the distance of the attracted point from the center of what would be an equivalent paraboloid, will produce an uncertainty of at

least several seconds, for a mountain equal to the one under consideration.

However, when the difference between the astronomical and geodetic latitudes is nearly a minute of arc, this method will give a value for the ratio of the density of the mountain, to that of the earth, in which the error is not greater than one-tenth of the whole amount. The difference between Playfair's reduction of the observations on Schiehallien and the generally accepted value is about one-fifth of the whole.

The last eruptions from Haleakala took place at least many hundred years ago. The natives have no traditions bearing on the fact; and geologists believe that the immense crater has come to its present condition by the sinking in of the top of the mountain and not by erosion. Both these would indicate a density of the mountain at least equal to its surface density: probably more. The pendulum adds testimony in this direction, and the zenith telescope observations at the foot of the mountain, indicate the same thing.

Therefore we may assert that the defect of gravity, usually noted on continental mountains, does not apply to those on small islands in the middle of a deep sea. Whether this supposed defect is caused by assuming an incorrect mean sea level, or whether the mountains are indeed only vertically and not horizontally displaced matter, we cannot now state. Both causes may exist: one certainly does.

On the Island of Hawaii there appears to be a striking example of plumb-line deflections. At Kohala we have a deflection of half a minute towards the south, and at Hilo, one, of quarter of a minute towards the north. These points are both on the windward coast and are distant from each other about sixty miles.

It is easy to see why there should be one to the southward, at Kohala, for the great mountain masses of Mauna Kea, Mauna Loa and Hualalai would all have this influence. But at Hilo there is no explanation unless we assume that the south side of the island, where the volcanoes are active, is much less dense than the north side, where the fires have been slumbering for centuries.

In general the deflections everywhere in the islands are greater than we expect, judging from analogy with continental masses: but here we have a surrounding sea which is much lighter than the land on which the continental mountains rest; and it is a question whether the sea bottom is really very much more dense than the average land. If the earth in solidifying has simply contracted unequally, and if each prism, having its base on the surface and its apex at the center, contains the same amount of matter, this would not make the bed

of the ocean very much more dense than the land. The depth of the ocean is about $\frac{1}{1000}$ of the earth's radius, and the volume of the prism would therefore be decreased by its $\frac{1}{333}$rd part. Hence, if we have the same amount of matter, the density should change by such amount This is entirely inadequate to counteract the effect of the light matter above, or materially change the deflections brought to light by the zenith telescope or by the pendulum.

It has been found that variations that arise from hidden causes under the Himalayas are two or three times as great as those that arise from the mountains themselves. The computations on which this result rests assume Young's rule, and take the ratio of the surface density to the mean density to be one-half. Besides, it is well known that the rule supposes the matter lying under the station to be a plain of infinite extent. The same rule has been applied to mountains, supposing them to be either cones, cylinders or the segments of a sphere. Evidently, in these latter cases, the error is in the direction of making gravity on top of a mountain too great, because the rule corrects additively for too great an amount of matter. In fact, to suit Haleakala, the constant factor in Young's formula should be changed from 1·25 to 1·36, and we should have

$$\frac{g_z}{g_0} = \left(1 - \frac{4}{3}\frac{z}{r}\right)$$

where the factor $\frac{5}{4}$ of the ordinary formula is here replaced by $\frac{4}{3}$.

This *increase* of the factor seems at first a paradox—but we must remember that the essential tendency of gravity is to diminish as we rise, and that any correction for matter is a positive quantity which must be added to this negative correction. Hence, for a cone, which contains less matter than the plain, the decrease of gravity should be greater, or the factor which corrects for the matter should be greater.

In fact, the factor that corrects for an infinite plain has only to be multiplied by a quantity depending on the cosine of the vertical angle of the cone to make it applicable to this figure. Supposing the cone to have a vertical angle of 180°, the two formulæ coincide, as they should do, since in this case our cone becomes an infinite plain.

Using the new formula

$$\frac{dg}{g} = 2\frac{h}{r}\left[1 - \frac{3}{4}\frac{\delta}{\Delta}(1 - \cos\beta)\right]$$

to get an improved mean density we arrive at 2·8—the decrease of gravity shown by the pendulums indicating a ratio of exactly $\frac{1}{2}$ for the two densities: gravity is first corrected for

elevation, the downward attraction of the cone is then added, and this compared with the actually observed decrease gives its density.

The conclusions drawn from the observations are therefore:

I. Deflections of the plumb-line are greater on island than on continental mountains, presumably on account of the lighter surrounding sea water; and gravity is not in defect because it is here estimated from the true sea level and not from a sea elevated by continental attraction.

II. Deflections appear to be greater in the vicinity of extinct volcanoes than near active ones.

III. The so-called "hidden causes," which in the case of the Himalayas give a variation of gravity several times as great as those arising from the attraction of the mountains themselves, do not exist in the Hawaiian Islands.

ART. XXXIV.—*Mineralogical Notes;* by S. L. PENFIELD and E. S. SPERRY.

1. *Beryl.*

IN connection with the previous communications on the chemistry of beryl from this laboratory,* we thought that it would be of interest to re-examine one of the beryls containing the most alkali to prove if possible the correctness of the assumption which we had made, that the alkalies when present replace the beryllium. For this purpose we selected the cæsium beryl from Norway, Maine, which had been previously analyzed and described in one of our former papers, and subjected it to a very careful chemical analysis by Mr. Sperry, with results which are given below. We also publish the chemical analysis of a transparent yellow beryl, known by some as *golden beryl*, from Litchfield Co., Ct., which is collected and used as gem material. The mineral was perfectly pure and was sent to us by Mr. Geo. F. Kunz, of New York. A third beryl which we have investigated is a transparent glassy variety from Willimantic, Ct., with very unusual crystalline habit, which was brought to our notice by Mr. H. N. Bill, of Willimantic, Ct., who collected it from a narrow vein of coarse granite, at an excavation for a roadway on Oak street, a short distance north of the residence of Mr. Joel Fox. The specimen is irregular in shape, not over 2½ inches in its greatest diameter, it is clear and glassy though much cracked and soiled by infiltrating clay, and with the exception of a small part,

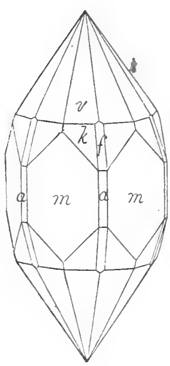
* This Journal, III, xxviii, 25, and III, xxxii, 110.

where it was broken off, is covered with crystalline facets very irregularly distributed, so that the system of crystallization can not readily be told. The most prominent face on the specimen is a prismatic face *m* measuring nearly one square inch in surface, but with irregular contour and deeply pitted by crystalline depressions scattered irregularly over its surface. At either end of this face and for a distance of one half an inch back, the crystal is terminated by a series of dihexagonal pyramids, or berylloids, in parallel position, there being six of them at one end and four at the other; these run into one another in a most confusing manner, while most of the specimen is covered with such a multitude of berylloid and prismatic faces, that their relation to each other can only be made out with difficulty, which is further increased by the somewhat curved and dull nature of the faces, so that they give only poor reflections on the goniometer. The forms which were identified are as follows:

m, $10\bar{1}0$, I	p, $10\bar{1}1$, 1	k, $42\bar{6}1$, $6\text{-}\frac{3}{2}$	f, $33\bar{6}1$, 6-2
a, $11\bar{2}0$, $i\text{-}2$	v, $21\bar{3}1$, $3\text{-}\frac{3}{2}$	n, $31\bar{4}1$, $4\text{-}\frac{4}{3}$	

Of these, *n* and *p* were identified only once. The common berylloid at the ends of the prism is *v* with the points rounded off as if they had been dissolved away. Where the berylloids join the prism, the steeper *k* faces are common. Fig. 1 represents the arrangement of these faces in a single ideal crystal, while the specimen in hand might be considered as an aggregate of such crystals, with prismatic faces in common terminated by a series of berylloid points. The whole mass has a very much eaten out or etched appearance, and the idea suggests itself that this unusual and curious development, so unlike our ordinary Connecticut beryl, has perhaps resulted from the action of some solvent upon a large mass of beryl. Although the angles obtained in measuring the faces are only approximate, the best of them agree closely with those calculated from Kokscharow's fundamental measurements,* while the determination was further facilitated by the occurrence of the faces in zones. The following angles were measured, and are given in the table, along with the calculated values, the number of times that different faces were measured and the limiting values.

1.



* Materialien zur Mineralogie Russlands, i, 147.

		Measured.	Calculated.	No. of times.	Limit.
$v \wedge v$	$3\bar{1}\bar{2}1 \wedge 2\bar{1}\bar{3}1$	31° 34′	31° 46′	4	30° 57′–31° 34′
$v \wedge v$	$2\bar{1}\bar{3}1 \wedge 1\bar{2}\bar{3}1$	18° 31′	18° 11′	4	18° 31′–19° 51′
$k \wedge k$	$6\bar{2}\bar{4}1 \wedge 4\bar{2}\bar{6}1$	36° 28′	37° 14′	2	35° 8′–36° 28′
$k \wedge k$	$4\bar{2}\bar{6}1 \wedge 2\bar{4}\bar{6}1$	20° 40′	20° 41′	2	20° 2′–20° 41′
$k \wedge f$	$4\bar{2}\bar{6}1 \wedge 3\bar{3}\bar{6}1$	10° 36′	10° 21′	2	9° 32′–10° 36′
$m \wedge v$	$10\bar{1}0 \wedge 3\bar{1}\bar{2}1$	37° 25′	37° 49′	2	37° 16′–37° 25′
$m \wedge n$	$10\bar{1}0 \wedge 4\bar{1}\bar{3}1$	28° 51′	29° 0′	1	
$m \wedge k$	$10\bar{1}0 \wedge 6\bar{2}\bar{4}1$	25° approx.	26° 8′	1	
$m \wedge m$	$10\bar{1}0 \wedge 01\bar{1}0$	59° 49′	60° 3′	1	
$v \wedge k$	$3\bar{1}\bar{2}1 \wedge 6\bar{2}\bar{4}1$	15° approx.	15° 6′	1	

The results of the chemical analyses of the three varieties are as follows:

I. Norway, Maine, Sp. Gr. 2·747, No. 409A in Professor Brush's collection.
II. Litchfield Co., Ct., Sp. Gr. 2·716.
III. Willimantic, Ct., Sp. Gr. 2·725, No. 410A in Professor Brush's collection.

	I.	Ratio.	II.	Ratio.	III.	Ratio.
SiO_2	64·12	1·069	65·62	1·093	65·72	1·095
Al_2O_3	17·89	·175	17·86	·175	18·40	·180
Fe_2O_3			·37	·002		
FeO	·16	·002	·18	·002	·26	·004
MnO					·12	·002
BeO	12·13	·485	13·50	·540	13·08	·523
Cs_2O	1·61	·007	·03			
K_2O	·10	·001			·12	·001
Na_2O	1·21	·029	·54	·009	·75	·012
Li_2O	·75	·015	·10	·003	·28	·009
Ign	2·24	·124	2·34	·130	2·06	·114
	100·21		100 54		100·79	

The ratios are as follows:

	SiO_2	: Al_2O_3	: RO	:	H_2O.									
I	1·069	·175	·539	:	·124	or	6	:	0·98	:	3·03	:	0·70
II	1·093	·177	·554	:	·130	or	6	:	0·97	:	3·04	:	0·71
III	1·095	·180	·551	:	·114	or	6	:	0·98	:	3·02	:	0·62

In the above ratios, RO includes all the protoxides (Be, Fe, Mn, Cs_2, K_2, Na_2, Li_2)O. In relation to the alkalies, it will be seen that in analysis I, the BeO is fully one per cent lower than in II and III, while by a consideration of the ratios it will be seen that this deficiency is fully made up by the presence of a sufficient quantity of alkalies. This is certainly the necessary proof of the correctness of our assumption that the alkalies in beryl are isomorphous with the BeO. In analysis I, if we neglect the alkalies, the ratio of $SiO_2 : Al_2O_3 :$ BeO becomes 6 : 0·98 : 2·72. In analysis II there is an unusual quantity of Fe_2O_3, which may account for the yellow color of the beryl; however, the results of the FeO and Fe_2O_3 determinations can not be regarded as very exact, owing to the difficulty of decomposing the beryl with hydrofluoric acid, though special care was taken to make the determination as exact as possible. Aside from the above-mentioned peculiarities, the analyses

present no special features which have not been noted in previous papers. The occurrence of alkalies and water, even in our most transparent and purest beryls, is well established. The water must still remain problematical. It has previously been determined as loss on ignition, but we have also made direct determinations by heating the mineral in a Gooch tubulated crucible, collecting the water in a chloride of calcium tube, with special care, and obtained results agreeing with the loss on ignition. If this water is to be included in the formula, we would suggest, as was done in a previous paper,* using the usually accepted formula of beryl, $Be_3Al_2Si_6O_{18}$, plus one-half a molecule of water. This expresses nearly the quantity which is present, while the excess, over 0·50 H_2O in the above ratios, may be accidental or perhaps even basic water, $3H_2O$ being equivalent to Al_2O_3 and H_2O to BeO. That all of the water is basic seems to us improbable, as it is present in too large proportion, and if added in any way to the Al_2O_3 and BeO, it would distort the simple ratio of $SiO_2 : Al_2O_3 : BeO$ to too great an extent. The excess of H_2O over and above one-half a molecule in the three analyses is I, 0·63 ; II, 0·70 ; III, 0·42 per cent. Such quantities of accidental water, as we may call it at present, are not uncommon in the analyses of our ordinarily accepted anhydrous minerals.

2. *Phenacite.*

Having proved that alkalies are almost always present in beryl, replacing the BeO, we decided to analyze a phenacite, with especial reference to the detection and estimation of any alkalies that might be present. The material, which was furnished to us by Mr. Geo. F. Kunz, of New York, was the flat rhombohedral variety from Topaz Butte, near Florissant, Pike's Peak region, Colorado. All of the material was clear and colorless and had a specific gravity between 2·966 and 2·957, determined by means of the heavy solution. The analyses are

	Sperry.	Penfield.	Mean.	Calculated for Be_2SiO_4.
SiO_2	54·46	54·42	54·44	54·47
BeO	45·57	45·60	45·58	45·53
Na_2O	0·21		0·21	
Li_2O	trace			
Ign.	0·26		·26	
			100·49	

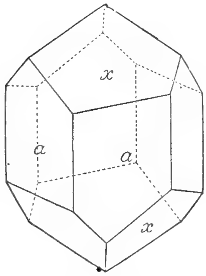
The atomic weights Be=9·08 and O=15·96 were used in calculating the above values, while for Be=9·4 and O=16·, the values are SiO_2=54·15 and 45·85. Special care was taken in the determination of the alkalies, the solutions coming in con-

* This Journal, III, xxxii, 110.

tact with glass only during the necessary filtrations. The slight trace is calculated as Na_2O, although it contained traces of lithia, as shown by the spectroscope.

Crystals from Mt. Antero, Colorado.—In a previous paper* one of us published a description of these crystals from a few specimens which belonged to the Rev. R. T. Cross, of Denver. During the summer of 1887, Mr. W. B. Smith, of Denver, Colorado, secured a large number of crystals, through a mineral collector, which are now quite largely distributed through mineral cabinets. The difficulty in securing the specimens is their occurrence at an altitude of over 12,000 feet, at a locality which is only accessible during a short period in the summer, after the snow has disappeared. The crystals are attached to quartz, transparent beryl (aquamarine, sometimes with good terminations), and Baveno twins of orthoclase, and are associated with muscovite and octahedral fluorite. All of the specimens which we have seen in the collections of Messrs.

2.



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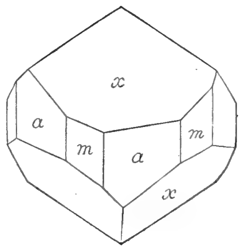


C. S. Bement, Geo. J. Brush, W. B. Smith, the Yale University cabinet and the U. S. National Museum show two prominent developments. One of these, according to our own observations and those of Mr. W. B. Smith, who has seen the greatest number and variety of specimens from this locality, always occurs among those crystals which are attached to quartz or beryl and is represented in its simplest form in fig. 2, which shows the combination of *a* ($11\bar{2}0$, i-2) and *x* ($\bar{1}3\bar{2}2$, $-r\,\frac{1}{4}\,(\frac{3}{2}\text{-}\frac{3}{2})$), giving a very interesting form, owing to the unusual combination of a prism of the second with a rhombohedron of the third order; sometimes there are associated, with these, small faces of *m* ($10\bar{1}0$, I), *s* ($21\bar{3}1$, $+r\,\frac{1}{4}\,(3\text{-}\frac{3}{2})$) *r* ($10\bar{1}1$, +1), and *d* ($01\bar{1}2$, $-\frac{1}{2}$) as represented in figs. 4 and 5 of the previous communication.† The second habit, which is found among those crystals which are attached to orthoclase, has two prisms well developed and is short prismatic, fig. 3,

* This Journal, III, xxxiii, 132. † Loc. cit.

frequently much shorter than represented in the illustration. Many of the crystals are of considerable size, measuring over one-half inch in diameter and one inch in length. The *x* faces on the larger crystals are always dull and rough and the prismatic faces vertically striated.

3. *Monazite from Alexander Co., N. C.*

Crystals of this mineral, from a locality about three miles east of the Emerald and Hiddenite Mine, were first brought to notice and described by Mr. Wm. E. Hidden,* who sent us several grams of very pure transparent crystals for chemical examination. It seemed especially desirable to have an analysis of such a pure, crystallized variety, owing to the fact that most analyses of monazite show a greater or less percentage of ThO_2, and the conflicting views relative to its relation to the mineral; i. e., that it belongs in the composition of the mineral, although the oxide ThO_2 has no chemical relation to the Ce_2O_3, La_2O_3 and Di_2O_3, or that it is present together with SiO_2 and H_2O as an impurity of thorite, $ThSiO_4$, H_2O. This latter view was advanced by one of us in a former paper,† being substantiated by analytical results and microscopic examination, but the former view is still held by many and is especially advocated by C. W. Blomstrand, who has recently published a detailed paper‡ on the subject.

The chemical analysis was made with great care by both of us, according to the method described in the previous paper. The specific gravity, taken with precision on a chemical balance, was found to be 5·203. The analysis yielded

	Sperry.		Penfield.		Mean.
P_2O_5	29·57	28·95	29·19	29·57	29·32
Mixed oxides	71·91	72·37	72·25		72·18
SiO_2	·24		·47		·32
Ignition	·17				·17

The determination of ThO_2 and CeO_2 in the mixed oxides and calculation of CeO_2 to Ce_2O_3 gave as the complete analysis:

			Ratio.
P_2O_5	29·32		·207
Ce_2O_3	37·26	$\div$ 328	·210
$(La, Di)_2O_3$	31·60		
ThO_2	1·48		·005
SiO_2	·32		·005
Ign.	·17		
	100·15		

The amount of thoria is very slight, really not greater than the SiO_2 as can be seen by the ratio $ThO_2 : SiO_2 = 1 : 1$, al-

* This Journal, III, xxxii, 207.

† This Journal, III, xxiv, 250.

‡ Geol. För. Förh., ix, p. 160, 1887.

though owing to its very high atomic weight it is represented by a much greater percentage in the analysis. The identity of the thoria was proved by making an atomic weight determination on ·0276 grams of the oxide and by converting it into sulphate which gave 228 instead of 232, an agreement as close as could be expected from the small quantities used. The joint molecular weight of the $(Ce, La, Di)_2O_3$ was found to be 328. The amount of ThO_2 is here too small to warrant any generalizations as to whether it is present as a silicate, which is certainly substantiated by our analysis, or whether it belongs to the phosphate. Regarding the ThO_2 and SiO_2 as present in the form of thorite, the P_2O_5 and $(Ce, La, Di)_2O_3$ are present in the proportion of a normal phosphate, as shown by the ratio, ·207 : ·210 = 1 : 1. ThO_2 can not be regarded as an essential constituent of monazite, as it is present in varying proportions, though almost always present in the different varieties.

4. *Sussexite from Mine Hill, Franklin, N. J.*

This rare mineral was first described by Professor Geo. J. Brush,* who determined its formula to be $HRBO_3$, where R = Mn and Mg. A new analysis of this mineral was to be desired, especially for the more accurate determination of the boric acid, which was made by the method proposed by Professor F. A. Gooch.† The material for analysis was taken from the original specimens in the collection of Professor Brush, the purest fibers being selected, which had a specific gravity of 3·123, taken very carefully on a chemical balance, after boiling in water to expel the air.

The analysis by Penfield yielded

		Ratio.		
B_2O_3	33·31	·476		1·00
MnO	38·08	·536		
ZnO	3·24	·040	·974	2·05
MgO	15·92	·398		
H_2O	8·53	·472		·99
Loss by drying at 250° C.	·90			
	99·98			

The air-dry powder lost 0·34 per cent by drying at 100° C. and 0·90 per cent at 250° C. Regarding this water as hygroscopic, the ratio of $Be_2O_3 : RO : H_2O = 1 : 2 : 1$ very closely, which fully substantiates the formula of Prof. Brush, $H(Mn, Mg, Zn)BO_3$.

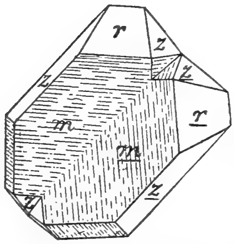
5. *Twin Crystals of Quartz with inclined Axes.*

Two twin crystals were recently purchased by Professor Geo. J. Brush, in London, labeled from Madagascar. As such crystals are very exceptional, we thought that a notice of them

* This Journal, II, xlvi, 240. † Am. Chem. Journal, ix, p. 23.

would not be without interest to the readers of the Journal. Crystals from Japan, with exactly the same habit, have been described and figured by G. vom Rath.* The two crystals in the cabinet of Professor Brush, which are each about one inch in greatest diameter, are very much flattened parallel to a prismatic face and have a pyramid of the second order, $1\bar{2}12$, 1-2 as twinning plane. The forms are those of the ordinary quartz combination, *m* ($10\bar{1}0$, I), *r* ($10\bar{1}1$, 1) and *z* ($01\bar{1}1$, –1) and are developed as shown in fig. 4. The *m* faces are strongly striated horizontally. The crystals seem to have been attached only at that part where the *r* and *z* faces make a small re-entrant angle, at the lower part of the twin. The crystals showed no decided pyro-electric phenomena.

4.



6. *Oligoclase from Bakersville, N. C., with abnormal optical properties.*†

The material which forms the subject of this investigation was sent to us by Mr. Norman Spang, of Etna, Pa., and later another fragment from undoubtedly the same locality was sent to New Haven by Mr. Geo. F. Kunz, of New York.

The mineral is remarkable for its purity, both pieces being as transparent as plate glass, the only things to mar the transparency being little bunches or tufts of minute crystals with radiated structure which are scattered sparingly and irregularly through the feldspar; these show no distinct form and cannot be referred to any definite species. The feldspar cleavages are well shown; one of them, the basal (001), is very perfect and easily obtained; the second, the brachypinacoid (010), is much less perfect, the mineral breaking with a conchoidal fracture so that it is hard to obtain a flat cleavage surface; there is also a tendency to break with an irregular conchoidal fracture parallel to the macropinacoid (100). The angle between the two cleavages, 001 and 010, was measured on two fragments which were carefully selected, but the results are not very satisfactory owing to the poor (010) cleavage. The best of these measurements is $001 \wedge 010 = 88° 2'$ (supplement), the second gave 88° 45′, but the reflections were poorer. If placed in position on the basal plane, the crystal would have an inclination of about 2° to the left. An interesting point in connection with this feldspar is that there is not a trace of twinning structure to be

* Pogg. Annalen, clv, 49.

† An account of this feldspar was given by Mr. G. F. Kunz, with an analysis by Prof. F. W. Clarke, in the September number, p. 222.

found on either fragment, a cleavage piece showing one square inch of surface on the basal plane, being perfectly flat and free from striations. The specific gravity is 2·651.

The following analysis was made by Mr. Sperry:

		Ratio.	Anorthite.	Albite.
SiO_2	62·60	1·043	·160 (2)	·883 (6·00)
Al_2O_3	23·52	·228	·080 (1)	·148 (1·00)
Fe_2O_3	·08			
CaO	4·47	·080	·080 (1)	
Na_2O	8·62	·139 }		·145 (·99)
K_2O	·56	·006 }		
Ign.	·10			
	99·95			

Disregarding the trace of Fe_2O_3 and H_2O, and calculating the SiO_2 and Al_2O_3 which would unite with the CaO to form anorthite (ratio $SiO_2 : Al_2O_3 : CaO = 2 : 1 : 1$), we find that the remaining constituents are in the right proportion to form albite (ratio $SiO_2 : Al_2O_3 : Na_2O = 6 : 1 : 1$). The ratio of anorthite molecule to albite molecule is 1 : 3·6, the per cent being:

Anorthite	$Ca_2Al_4Si_4O_{16} = 22·32$
Albite	$Na_2Al_2Si_6O_{16} = 77·45$

The above chemical results are sufficient to classify this mineral as oligoclase.

The most interesting and important thing in connection with this mineral is that its optical properties are very far from those of oligoclase. Sections parallel to the basal plane do not show the extinction of oligoclase +1°, but the very large angle +39° to 40°. The positive nature of this angle was determined very carefully on the two fragments whose cleavage angles were measured. The extinctions were measured with a Fuess microscope, and in the two sections varied from 38° 30′ to 40°. Sections parallel to the brachypinacoid did not show any change from light to dark in ordinary polarized light when the sections were turned, but in convergent light showed an optic axis, as nearly as one could tell, exactly in the center of the field. When the cleavage lines are parallel to the principal planes of the polarizer and analyzer, the dark bar running through the axis is almost parallel to the cleavage lines. A similar section of oligoclase should show an extinction of +5°, and in convergent light a bisectrix almost in the center of the field.

We regret that we cannot give any facts regarding the mode of occurrence and associations of this interesting feldspar, but must leave that for others who may be so fortunate as to study this mineral in the field. A study of the crystals, if any are to be found, is also to be desired.

7. *Barium Feldspar from Blue Hill, Delaware Co., Pa.; the* CASSINITE *of Dr. I. Lea.**

Professor F. A. Genth† was the first to show that this was in any way an interesting and distinct variety by his analysis, which showed that the feldspar contained nearly four per cent of BaO; his results, however, yielded no definite formula, and could not be correctly interpreted without an optical examination.

Our investigations were made on very good cleavage specimens in the Yale University cabinet. A section parallel to the base (001) shows that the mineral is a mixture, composed chiefly of a monoclinic feldspar with interpositions of a plagioclase (albite) with fine striations and small extinction angle. The albite appears as streaks running through the section parallel to the ortho-axis *b*; these streaks have nearly a uniform width of about $0{\cdot}05^{mm}$, a varying length of usually less than 1^{mm}, and taper off slightly toward the ends, which are rounded. They are distributed quite evenly through the section, with usually a clear space of $0{\cdot}5^{mm}$ between the streaks. In the section parallel to the clinopinacoid (010), the streaks are much more conspicuous. The plagioclase has an extinction of $+18°$, which would indicate that it is nearly pure albite; the monoclinic feldspar has an extinction of $+6°$ like orthoclase, it also shows in convergent light an obtuse bisectrix. The difference in the extinction angles makes the albite streaks more conspicuous than in the basal section, the streaks being parallel to the vertical axis *c*; they have the same width as in the basal section, $0{\cdot}05^{mm}$, but usually a greater length, the longest being 2^{mm}; they are also more tapering. The albite is therefore interposed in thin plates parallel to the orthopinacoid, with the cleavage continuous in the two minerals. From the frequency and thickness of the albite streaks it seems as though it would make up not more than one-tenth of the total bulk of the feldspar. In the clinopinacoid section it is also seen that the material in which the albite is imbedded is not homogeneous but is streaked by a series of very narrow bands parallel to the vertical axis, *c*; these are very evenly distributed through the orthoclase and show the same extinction as the albite. It is probable that these microscopic interpositions, parallel to the larger ones, are also albite and they give in polarized light, when one of the minerals is dark, a curious vein-like, striated appearance to the section. Each of the larger streaks of albite is surrounded for a distance of about $0{\cdot}01^{mm}$ with a zone of pure feldspar, which contains none of these minute streaks of albite; this makes the contrast between the wider streaks of albite and the mono-

* Proc. Acad. Nat. Sci. Philad., 1866, 110. † Report Min. Penn., 1876, 224.

clinic feldspar all the more marked in polarized light, for if the albite is dark it will be surrounded by a border of homogeneous light material, the whole being imbedded in a gray streaked ground-mass which has the optical effect of an orthoclase, because the microscopic albite interpositions are subordinate to the monoclinic feldspar.

We hoped that at least a partial separation of the albite and the monoclinic feldspar could be made by means of the heavy solutions, but in this we were disappointed; the cleavage being continuous in the two minerals prevents a good mechanical separation by powdering, and the difference in specific gravity was too slight to yield good results. All of the powder had nearly a uniform specific gravity. That which was taken for analysis sank in the Thoulet solution of sp. gr. 2·642, leaving about half of the powder floating. The following analysis, which was made by Mr. Sperry, showed traces of Mn, Mg and Sr, but they were too minute to be determined. The mean of three analyses by Professor Genth is also given for comparison:

	Genth.	Sperry.	Ratio.		Anorthite.	Albite.	BaK feldspar.
SiO_2	62·60	62·95	1·049		·010 (2)	·384 (6)	·655
Al_2O_3	19·97	19·82	·192		·005 (1)	·066 (1)	·121
Fe_2O_3	·12	·17					
CaO	·19	·25	·005	·186	·005 (1)		
Na_2O	4·31	4·01	·064			·064 (1)	
BaO	3·71	3·95	·026				·117
K_2O	8·95	8·57	·091				
Ign.	·19	·11					
	100·04	99·83					

In the above the ratio of $Al_2O_3 : RO = ·192 : ·186$, almost 1:1. Regarding the small amount of CaO as belonging to anorthite, and uniting it with the albite to form a plagioclase, we can divide our analysis into two parts which will probably represent the mixture very closely:

Na,Ca feldspar, Albite.		K, Ba feldspar, Monoclinic.		K, Ba feldspar, Calculated to 100.	Ratio.	$K_2Al_2Si_6O_{16}$.	Ba feldspar.
SiO_2	23·64	SiO_2	39·31	61·12	1·019	·852 (6)	·167 (4)
Al_2O_3	7·33	Al_2O_3	12·49	19·42	·188	·147 (1)	·041 (1)
CaO	·25	BaO	3·95	6·14	·040		·040 (1)
Na_2O	4·01	K_2O	8·57	13·32	·142	·142 (1)	
	35·23		64·32	100·00			

In the 64·32 per cent of the monoclinic K, Ba feldspar the ratio of $SiO_2 : Al_2O_3 : RO = 5·60 : 1·03 : 1$, which gives no simple formula if we regard it as a homogeneous mineral. If, however, we regard it as composed of a potash feldspar $K_2Al_2Si_6O_{16}$ and a barium feldspar, deducting the ratio of $K_2Al_2Si_6O_{16}$ we have left $SiO_2 : Al_2O_3 : BaO = ·167 : ·041 : ·040$, almost exactly 4 : 1 : 1.

Our knowledge of the barium feldspars is confined to analyses of the mineral from a few localities. For the sake of comparison we quote the following:

I. Binnenthal, Switzerland, analysis by Stockar-Escher.*
II. Jakobsberg, Sweden, analysis by L. J. Igelström.†
III. Unknown locality, analysis by Pisani.‡

	I.	Ratio.	II.	Ratio.	III.	Ratio.
SiO_2	52·67	·878	53·53	·892	55·10	·917
Al_2O_3	21·12	·205	23·33	·226	23·20	·225
Fe_2O_3					·45	·003
CaO	·46	·008			1·83	·033
MgO	·04	·001	3·23	·081	·56	·014
BaO	15·05	·098	7·30	·047	7·30	·048
Na_2O	2·14	·034			7·45	·120
K_2O	7·82	·083	11·71	1·25	·83	·009
Ign.	·58				3·72	
	99·88		99·10		100·44	

The ratios in the three analyses are as follows:

	SiO_2 : Al_2O_3 RO
I.	·878 : ·205 : 224=4 : 0·93 : 1·02
II.	·892 : ·226 : 253=4 : 1·01 : 1·13
III.	·917 : ·225 : 224=4 : 0·98 : 0·98

All of these analyses have a ratio of $SiO_2 : Al_2O_3 : RO = 4 : 1 : 1$ and a formula $RAl_2Si_4O_{12}$; but one thing is very noticeable, that in all, the RO is very variable. In I, which is that of the purest hyalophane, the ratio of $BaO + (Ca, Mg)O : K_2O + Na_2O = 1 : 1$, and some have proposed that the feldspar is a mixture of $K_2Al_2Si_6O_{16}$ and a Ba feldspar like anorthite, $BaAl_2Si_2O_8$, similar to Tschermak's theory for the plagioclase feldspars. If, however, II and III are to be referred to hyalophane, we cannot accept this last hypothesis, but must accept for the formula of the species $RAl_2Si_4O_{12}$, R=Ba, Ca, Mg, K_2, Na_2.

Going back to our own analysis, it seems best to regard the feldspar as a mixture of 35·23 per cent of albite, 51·15 per cent of orthoclase and 13·17 per cent of hyalophane, $BaAl_2Si_4O_{12}$. The two latter are monoclinic, and have either grown together as isomorphous mixtures or, if in any other way, the optical properties are such that the relation to the two minerals can not be told. It must be noted also that in making this supposition it is necessary to regard the hyalophane as a pure barium feldspar; we see, however, no other way to interpret our analysis. If we regard our barium feldspar as united with potash to form a hyalophane like that from the Binnenthal, then the excess of potash cannot be united with Al_2O_3 and SiO_2 to form

* Kenngott, Uebersicht der Min. Forsch., 1856–57, p. 107.
† Bull. Soc. Min. de France, vi, 139.
‡ Bull. Soc. Min. de France, i, 84.

any simple compound, while the supposition which we have made gives ratios which are very simple and exact.

8. *A very pure magnesia mica, phlogopite, from Edwards, St. Lawrence Co., N. Y.*

Our attention was first called to this mineral by Mr. C. D. Nims of Philadelphia, N. Y., who had obtained it from the talc mines in Edwards. Later one of us,* while making a mineralogical excursion in St. Lawrence Co. under the auspices of the U. S. Geological Survey during the summer of 1887, visited the locality and was generously supplied with material by Mr. T. J. Hooper, superintendent of the Anthony Mine of the Adirondack Pulp Co.

The mineral occurs filling a narrow seam or vein associated with tremolite and the pure white talc which is extensively mined in that region. It occurs in large plates, without regular crystalline outline except an occasional hexagonal marking, which are more or less bent and intergrown. The cleavage is not quite as good as in most micas, being more like that of ripidolite; the folia are elastic when very thin but thicker folia, over $0{\cdot}1^{mm}$, crack and break quite readily in three directions parallel to the fracture figure. Thin plates of the mica appear perfectly clear and colorless; plates 2^{mm} thick and over have a very delicate sea-green color, thick pieces being exceedingly light colored and transparent, for a mica, in the direction of the vertical axis. The six-rayed fracture figure (*Schlagfigur*, German) and the pressure figure with rays at right angles to it are obtained by driving a steel point into the plates or pressing with a steel rod with rounded end against thin plates on an elastic support. The optical properties are not constant, even in the same plate. In convergent polarized light many pieces give a uniaxial interference figure, but usually the dark cross opens into hyperbolæ always showing a small optic axial angle; this was not measured because it was so variable. The plane of the optic axes is the plane of symmetry, parallel to one of the rays of the fracture figure, making it a mica of the second kind. The double refraction is negative.

Before the chemical analysis or any tests were made the nature of this mineral was questionable, such minerals as brucite, a highly crystallized variety of talc or a light colored ripidolite, suggested themselves rather than mica.

The specific gravity of the mineral was taken very carefully on the chemical balance, after boiling, to expel any air from between the folia, giving 2·793 and 2·791. The following analysis is by Mr. Sperry:

* Penfield.

	I.	II.	Mean.	Ratio.
SiO_2	44·82	44·81	44·81	·747
Al_2O_3	10·84	10·90	10·87	·106
FeO	·35	·28	·31	·004
MgO	28·91	28·89	28·90	·722
K_2O	8·33	8·47	8·40	·089
Na_2O	·33	·46	·38	·006
Li_2O	·09	·07	·08	·003
H_2O	5·44	5·41	5·42	·301
Loss at 100°	·98	·94	·96	·053
			100·13	

The analysis shows that the mineral is essentially a phlogopite but no relation between the constituents can be detected which can be expressed by a simple formula. Comparing it with other analyses, especially the recent ones given in Tschermak's article "Die Glimmergruppe"* we notice that it has about the same percentage of SiO_2, MgO and K_2O, less Al_2O_3 and Fe_2O_3, the latter we expect from its unusually light color, more H_2O and no fluorine, which is a little surprising as all previous analyses have shown from 0·8 to over 4·0 per cent of F.

If we seek out in our analysis the molecules which Tschermak regards as characteristic for the micas,

$$K = Si_6Al_6K_6O_{24} \text{ ratio of } SiO_2 : Al_2O_2 : K_2O = 2:1:1$$

and $$M = Si_6Mg_{12}O_{24} \text{ ratio of } SiO_2 : MgO = 1:2$$

we find that they are present in the following proportion together with a residue.

K.		Ratio.	
SiO_2	12·72	·212	(2)
Al_2O_3	10·87	·106	(1)
K_2O	8·40	·089	(1)
Na_2O	·38	·006	
Li_2O	·08	·003	
H_2O	·14	·008	
	32·59		

M.		Ratio.	
SiO_2	21·77	·363	(1)
FeO	·31	·004	(2)
MgO	28·90	·722	
	50·98		

Residue.		Ratio.	
SiO_2	10·32	·172	(1)
H_2O	5·28	·293	(2)
loss at 100°	·96	·053	
	16·56		

We find that there is 32·59 per cent of the K molecule in which the protoxide is almost wholly K_2O, a little Na_2O, Li_2O and H_2O being required to make the ratio 2 : 1 : 1. The M molecule is a very pure magnesia silicate while the 16·56 per cent of residue is a very pure ortho silicic acid H_4SiO_4, or if desired $Si_6H_{24}O_{24}$ with the ratio of $SiO_2 : H_2O = {·}172 : {·}346 = 1 : 2{·}01$. It is necessary here to include the H_2O which was lost at 100° C., the analysis being made on air-dry powder. The phlogopites contain more acid than the ordinary micas which are made up of mixtures of the K and M molecules.

* Zeitschr. Kryst., iii, 143.

Tschermak regards this excess of acid as comprised in the molecule $S = Si_{10}H_8O_{24}$ or the fluorine compound $Si_{10}O_8F_{24}$. The ortho-silicate which we find in this analysis, however, H_4SiO_4, seems a more natural compound to be associated with the other ortho-silicate molecules K and M.

If we do not follow Professor Tschermak in discussing the results of our analysis, as we have done above, we can detect a certain relation between the constituents. By taking one-seventh of the SiO_2 in the above ratio as unity we obtain

	SiO_2	Al_2O_3	(Mg, Fe)O	(K, Na, Li)$_2$O	H_2O
	7	0·99	6·80	0·92	3·31
nearly	7	1·	7	1	3

and if the excess of the H_2O above 3·00 is regarded as replacing MgO and K_2O, the ratio would be almost exactly whole numbers. This ratio and the composition of the mineral may be expressed by the somewhat elaborate formula $H_6K_2Mg_7Al_2Si_7O_{28}$. The acid radical Si_7O_{28} shows that the mineral is an orthosilicate, while the following percentage composition calculated from the above formula shows how closely it corresponds to the results of the analysis:

	SiO_2	Al_2O_3	MgO	K_2O	H_2O	
Theory	44·16	10·83	29·44	9·89	5·68	= 100·00
Analysis	44·81	10·87	29·06	9·25	6·38	= 100·37

The above analysis is like the original in our article except that the FeO has been calculated to an equivalent of MgO and the Na_2O and Li_2O to an equivalent of K_2O. Although it will not do to make any general statement regarding the chemical composition of phlogopite from one single analysis we offer the above results as a contribution to the chemistry of the micas, feeling assured that they are derived from exceptionally pure material.

In closing, we wish to express our thanks to those persons who have assisted us in our work by furnishing the material for carrying on these investigations, and whose names have been mentioned in our article.

Mineralogical Laboratory, Sheffield Scientific School,
July 19th, 1888.

ART. XXXV.—*On the Absorption Spectra of certain Blue Solutions.* (From Spectro-photometric Determinations by Mr. F. B. PITCHER.)

[Contributions from the Physical Laboratory of Cornell University. Communicated by Edward L. Nichols.]

II.

BLUES and violets obtained by absorption in pigments and solutions, differ in several respects from those colors which approximate in hue to the longer wave-lengths of the spectrum. They are much less completely saturated, as a rule, and they show irregularities of composition, not commonly met with in absorption reds and yellows.

It is an easy matter, for instance, to find reds the absorption spectra of which show no rays lying beyond the D line, but blue solutions transmit all the wave-lengths of the visible spectrum in considerable quantity; so that an attempt to isolate a pure absorption blue, by increasing the density of the solution or the thickness of the absorbing layer, or by diminishing the intensity of the light traversing the latter, results in the extinction of the shorter wave-lengths along with those lying in the green, yellow and red. It is moreover a matter of common knowledge among spectroscopists that the absorption spectra of very many blue substances, possess a more or less prominent red band, with indications frequently of selective absorption in other regions.

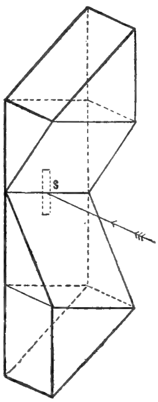
In view of the fact that precise knowledge of the distribution of energy in the visible spectra of this class was almost entirely lacking, our acquaintance with them being for the most part confined to what may be learned by inspection, it seemed of interest to submit the solutions of certain characteristic substances of the class in question, to a spectro-photometric analysis. This has been done, under the writer's direction, by Mr. F. B. Pitcher, from whose Thesis upon this subject the measurements to be described in this paper have been taken.

Mr. Pitcher's method differed in few important particulars from that employed by the writer in his "Spectro-photometric Study of Pigments," already described in these pages.* The spectro-photometer was one of Glan's pattern, in which the very ingenious, but far from sensitive, polarizing apparatus had been removed; its place being supplied by a pair of Nicol's prisms before the slit. To the right hand of the spectroscope slit and distant from the same about 60^{cm}, was placed the comparison flame, an Argand gas burner. Its rays, having been rendered parallel by passage through a lens of short focal length, passed through the two Nicol's prisms already referred

* This Journal, vol. xxviii, p. 342.

to and entered the lower half of the slit, after total reflection in a pair of small right-angled prisms. At a somewhat greater distance to the left of the slit, was placed a similar Argand burner without a condensing lens; its rays entering the upper half of the slit through another pair of reflection prisms. Between this second flame and the slit was a cell with faces of plane-parallel glass, within which were placed the solutions to be studied. The layer of liquid thus interposed was 1^{cm} in thickness. Figure 1 shows the arrangement of these four reflection prisms. In this excellent device, which is due in part to Crova, the edges of the inner prisms are in contact with each other and with the slit. The spectra of the two sets of rays, thus introduced into the collimator tube, appear therefore with sharply defined adjacent boundaries, separated only by a black line. Corresponding wave-lengths are in the same vertical plane and it only remains to isolate in turn the various regions to be compared, by means of an adjustable diaphragm in the eye-piece, and to bring the two spectra to equal intensity, in each region successively, by means of the Nicol's prisms.

1.



In its complete form, this type of spectrophotometer should have two sets of Nicol's prisms. One pair in the path of each ray, the inner Nicol of each pair being fixed with its plane of polarization parallel to the slit. This arrangement is advisable whenever the brilliancy of the ray under investigation is considerable; and it becomes necessary whenever in any region the intensity exceeds that of the corresponding portion of the comparison spectrum.

The instrument in such a case possesses the advantage of complete symmetry. The two rays are reflected the same number of times and at the same angles. They enter the collimator tube polarized in the same plane, and throughout their entire passage to the eye they suffer precisely similar treatment.

There are, however, a great many cases, notably in the study of the light reflected by pigments, and of absorption spectra, where the transmitted ray suffers marked diminution, in which the loss by polarization is such as to render advisable the removal of the second pair of Nicol's prisms. This may be done, whenever it becomes necessary, in order to obtain the requisite brightness of all parts of the spectrum, as in the case of the measurements now under consideration, without sensibly vitiating the accuracy of the determinations.

The instrument having been arranged in the manner already described; the glass cell was placed in the path of the rays

from the second Argand, and the intensity ratio between the spectrum thus transmitted and that of the comparison flame was obtained for nine regions, lying between the A line and the G line of Fraunhofer.

The wave-lengths of these regions, were as follows:

Region.	Wave-length.
1	7670
2	6770
3	6150
4	5630
5	5235
6	4940
7	4720
8	4525
9	4360

These readings afforded a correction-factor for each region of the spectrum, by means of which the selective absorption due to the glass cell and the condensing lens could be eliminated.

Solutions were then made of a number of blue pigments. Three of these were of known composition, namely, Prussian blue, artificial ultramarine and indigo. Five others were commercial preparations of "bluing" of unknown composition. These were included in the list, at the writer's suggestion, for the purpose chiefly of testing the applicability of the spectrophotometric method to the detection of such coloring matters as are not amenable to the ordinary spectroscopic analysis.

The strength of the solutions was so chosen in each case as to show decided color, and at the same time to transmit easily-measurable quantities of light throughout the spectrum. The results were indicated by means of curves, wave-lengths being taken as abscissæ, percentage of light as ordinates; that transmitted by the empty cell in each region being taken as unity for that particular region.

Figure 2 shows the curves thus obtained for ultramarine (curve *a*), indigo (curve *b*) and Prussian blue (curve *c*). They exhibit the nature of the selective absorption excited by each solution upon the rays traversing it. The horizontal line at the top of each diagram may be considered as representing the brightness of the spectrum of the rays passing through the empty cell, as compared with that of the light transmitted by the solution under investigation. Vertical distances from that line to the curve measure the degree of absorption in each portion of the spectrum. Each curve is characteristic of the solution to which it pertains and, in so far as the number and position of the maxima and minima are concerned, it is independent of the strength of the solution.

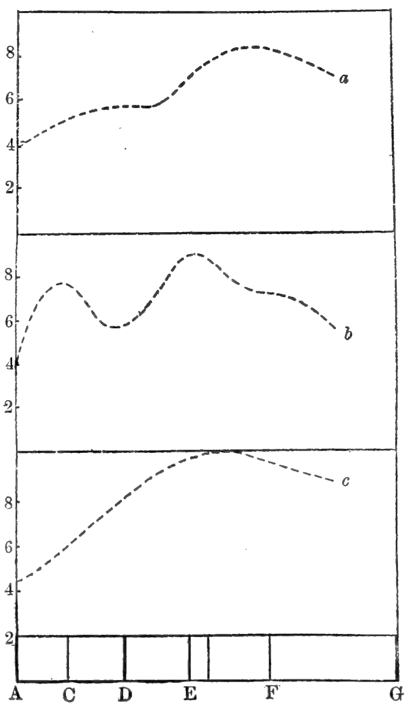
These results afford an excellent illustration of the use of the spectro-photometer in the location of absorption bands not

sufficiently marked to be identified by ordinary inspection, and in the detection of regions of maximum brightness in spectra which to the unaided eye do not exhibit any such peculiarity.

The measurement of the five commercial blues gave curves, which approached so nearly to those obtained in the case of the three pigments already mentioned, as to leave no question as to the nature of the substance to which each of them owed its color. Indeed the ease and certainty with which the pigment could be identified was such as to warrant the belief that by the use of this instrument a large number of absorption spectra, which are quite beyond the reach of the spectroscopic methods now in vogue, may be identified with the same degree of certainty which now attends the recognition of blood or chlorophyl. To this end the first step must be the careful determination of a large number of characteristic curves pertaining to the various solutions to which the method is to be extended. This having been properly done, the identification of solutions in which selective absorption takes place to a measurable extent, will be in most cases a comparatively simple matter.

Mr. Pitcher's experiments were also extended to two interesting solutions in which the addition of an alkali produces a change of color. These, which represent quite distinct classes, were litmus solution and the sulphate of copper. The results are shown in figures 3 and 4. The litmus solution was taken in its three characteristic conditions, acid, alkaline and neutral. The acid solution (figure 3, curve *d*), is marked by almost complete transparency to rays of the regions between B and C, and to slight minima in the neighborhood of the D line, and just beyond F. The addition of ammonia, until the well known color-change indicative of neutrality took place, brought about a modification of the curve to the form shown in curve *e*. The bright region in the red disappeared; the absorption in the yellow was increased, and the brightness of the remainder of the spectrum was diminished, by

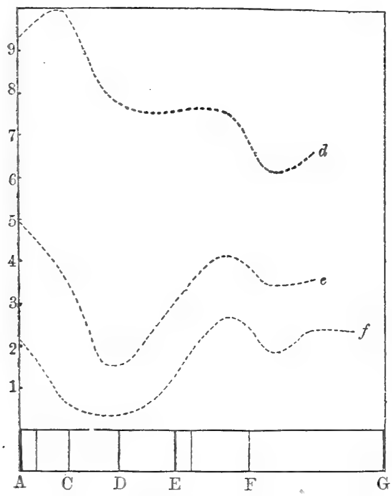
2.



about one half. The addition of ammonia, to the extent necessary to produce the color-change denoting alkalinity, further widened and deepened the absorption band in the yellow and increased the absorption throughout the entire spectrum. The diminution in intensity was greater in the red, however, than in the regions lying beyond the great absorption band.

For the determination of the influence of ammonia upon copper sulphate, a concentrated solution of the salt was prepared and its curve obtained by the method already described.

3.



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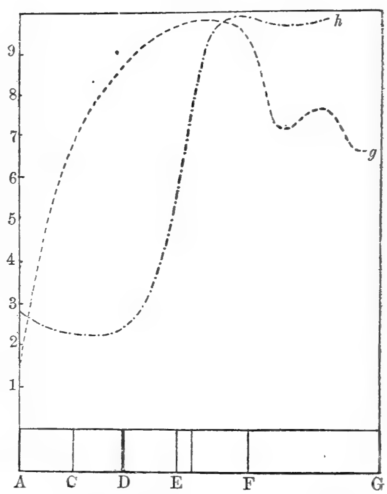


This solution when viewed by transmitted light, in a layer only one centimeter in thickness, shows but feeble color, and the intensity curve (figure 4, curve *g*), indicates but little absorption excepting in the extreme red. Noteworthy is the well-marked maximum between the E and F lines and the relatively large amount of absorption in the violet.

The addition of ammonia was found to produce strong absorption throughout the orange and yellow, the minimum corresponding in position with that observed in the case of alkaline litmus (curve *f*). Beyond the point of maximum, between E and F, in the curve of the neutral salt, the ammonio-sulphate had become almost completely transparent, with just a trace remaining of the small absorption band lying beyond the F line. (See curve *h*.)

The almost untouched domain of the spectro-photometric investigation of absorption spectra is an extensive one and by no means devoid of interest. The writer hopes ere long to add to the present contribution, studies of some of the aniline colors and of the influence of acids and alkalies upon the spectra of the so-called "color-test" solutions.

August 1, 1888.

Art. XXXVI.—*An Instrument for Demonstrating the Laws of Transverse Vibrations of Cords and Wires;* by George S. Moler, A.B., B.M.E.

[Contributions from the Physical Laboratory of Cornell University. Communicated by Edward L. Nichols.]

This piece of apparatus was designed to meet a want, felt in the laboratory, for an improvement over Melde's method of producing transverse vibrations of cords and wires.

It seemed desirable to produce a circular vibration which would appear of the same amplitude when viewed from all sides and which could be maintained for an indefinite length of time; so that the proper adjustments of length or of tension could be made while the cord was in motion. It also seemed desirable to maintain a constant rate of vibration when cords are used which offer more or less resistance to the motion.

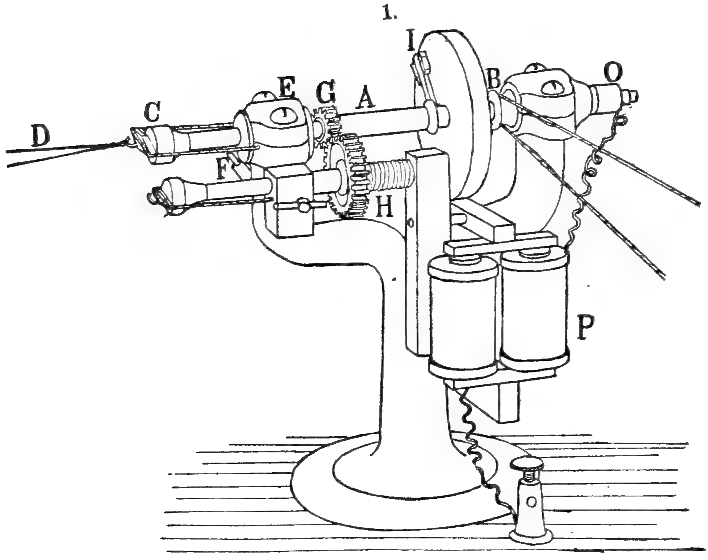
The general arrangement of the apparatus is shown in figure 1. To produce the circular vibrations the cord is attached to a crank of small throw, which is kept at a constant but high rate of speed by means of a regulator. A is the main shaft, driven by a belt running over a pulley at B. Upon the crank-pin at C is a small block having a hook to which the cords D are attached. To prevent the tension of these cords, which may sometimes amount to four or five kilograms, from exerting a pull upon the shaft and thereby greatly increasing the friction, a cord is carried from the box E to the block C through holes in each end of the latter and back to the box E; then to a tightening pin F as shown in figure 2. This device allows the block to move freely and easily under the largest loads.

At G is a pinion which drives another shaft with a similar crank and block. On this shaft is a spring which holds the wheel H in line with the pinion. This wheel is fastened to a slotted sleeve which, when it is not desirable to drive both cranks at the same time, can be moved, by compressing the spring, until it slides past a pin in the shaft. A turn of the sleeve then holds the wheel in a position where it will not engage with the pinion.

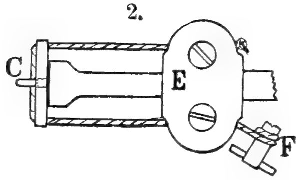
From these cranks the cords are carried, as shown in figure 5, to two movable blocks which can be clamped at any desired position upon the base of the instrument. These blocks carry small pulleys over which the cords pass, the ends of each cord being fastened to a scale pan and the proper tension secured by the use of weights.

A cord one meter long is commonly used, but the apparatus works quite as well with shorter or indeed with much longer

1.



2.



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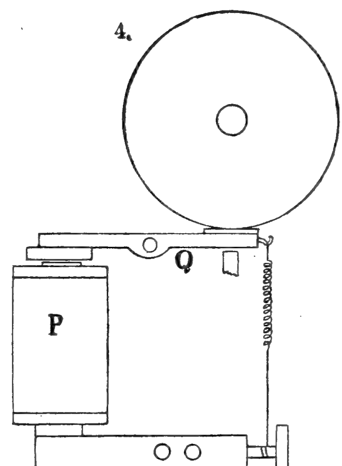
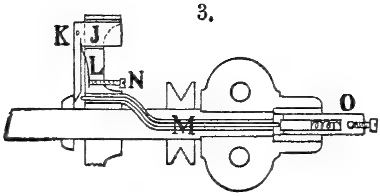
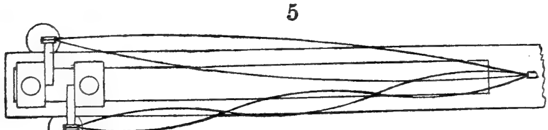


3.



5



cords. By carrying a cord as far as I conveniently could, a distance of thirty-four feet, and adjusting the tension, I obtained twenty-five well formed segments.

The regulating device is an electrical governor, shown at I figure 1, but more in detail in figure 3. The lever J is pivoted at K and whenever the speed exceeds a certain amount it is pulled outward with sufficient force to bend the spring L and make contact with the insulated wire M. The speed at which this occurs is regulated by altering the tension of the spring by means of the screw N. The contact points are of platinum. The insulated wire runs out through the hollow shaft to the binding post O, thence to the electro-magnet P and the battery. The other pole of the battery is connected with the frame of the machine. The armature of the electro-magnet is attached to a lever Q (fig. 4), and upon the other end of the lever is a leather pad, which is brought into contact with the wheel whenever the circuit is closed. The friction thus produced reduces the speed until the contact breaks when the speed again increases and closes the circuit. The delicacy of this device is such that these variations of speed are imperceptible.

By driving two cords from the same crank a very accurate secondary speed regulation was obtained. For this purpose a cord of considerable mass was made use of, with tension such as to cause it to vibrate in a single segment. The shaft was driven by means of a small turbine motor, capable of any speed up to seven thousand revolutions per minute. When the vibrating segment of the heavy cord was once well formed it was found that small variations in the motive power made themselves felt in swelling or diminishing the amplitude of the segment without producing changes in speed, and that it was possible to make all necessary adjustments of length or tension in the second cord without in any way interfering with the uniform motion of the instrument. If, however, the governing segment were destroyed in any way the electrical governor already described would soon restore the speed to its normal amount. The amplitude of the governing segment served likewise as a delicate indicator of the condition of the motive power, excess of power causing a swelling out of the segment to large diameter, and diminution of power showing itself by decrease in the amplitude of vibration.

By means of this apparatus all the laws demonstrated in Melde's experiment may be verified. The following is the record of a single set of observations made to test the working of the instrument.

The cords used were of braided silk, measuring $\cdot 55^{mm}$ in diameter. Four strands of this size were taken for the control-

ling cord. This was attached to the crank of the main shaft and with a load of 2·5 kilograms gave a speed of 4986 revolutions, as a mean of four consecutive determinations; the greatest variation from the mean being 10 revolutions, which error lies within the limit of accuracy of the determination. At this speed the controlling cord was formed into a single segment having a diameter of about 8^{cm}.

During the first half of the experiment, in addition to the controlling cord, a single cord was used. It was then replaced by four strands and finally by a single cord driven from the second crank.

Now if N be the number of vibrations per unit of time, L the length of the cord, n the number of segments and V the velocity of transmission of an impulse transmitted to the cord, we have the familiar formula expressing the transverse vibrations of flexible cords;

$$N = \frac{n}{2L} V.$$

If P is the tension of the cord, s its cross section and d its density: we shall have

$$V = \sqrt{\frac{P}{sd}}.$$

Finally if λ is the wave length,

$$\lambda = \frac{2L}{n},$$

$$V = N\lambda,$$

and $$\sqrt{\frac{P}{sd}} = \frac{n}{N2L}.$$

In the following table the single set of observations already referred to are given, for the purpose of exhibiting the performance of the apparatus under variations of cross section, length, speed and tension. The results agree quite closely, obtained as they were from a single determination of each quantity, and they show the application of the apparatus to the demonstration of the laws embodied in the general formula.

A very interesting form of vibration is obtained by stretching a cord at 45° with the line of the shaft. The crank then gives a longitudinal impulse and a transverse impulse at the same time; the longitudinal impulse being an octave lower than the transverse. The cord thus has a resultant motion in which its vibrations as a whole and in two segments are plainly

TABLE.

Observation.	Cross Section. S.	Length. L.	Rate of Vibration. N.	Number of Segment. *n*.	Tension in Grams. P.	Square root of Tension. $\sqrt{P}$	Constant $\frac{n}{NL}\sqrt{\frac{P}{sd}}$
No. 1	1 strand.	1	2	1	627·	25·04	12·52
" 2		1	2	2	162·	12·70	12·70
" 3		1	2	3	74·	8·60	12·90
" 4		1	2	4	41·	6·40	12·80
" 5		1	2	5	26·	5·10	12·75
No. 6	1 strand.	1	2	1	627·	25·04	12·52
" 7		$\frac{2}{3}$	2	1	266·	16.30	12·22
" 8		$\frac{1}{2}$	2	1	166·	12·90	12·99
No. 9	4 strands.	1	2	1	2500·	50·00	12·50
" 10		1	2	2	625·	20·00	12·50
" 11		1	2	3	280·	16·70	12·52
" 12		1	2	4	158·	12·60	12·60
No. 13	1 strand.	1	1	1	166·	12·90	12·90
" 14		1	1	2	41·	6·40	12·80
" 15		1	1	3	18·	4·20	12·60
" 16		1	1	4	9·5	3·10	12·40

visible. By interposing a long narrow slit between the cord and a strong light, a single point may be illuminated, which when the cord is in motion, traces in the most beautiful manner, by persistence of vision, the path of that portion of the vibrating segment. By the use of a series of parallel slits any number of such illuminated paths may be made visible at once, bringing out the character of vibration of the entire segment with an indescribably striking effect. The curves followed by the illuminated points are Lissajou's figures and kindred forms. The regulation attained by means of the controlling cord is so excellent that it was found possible to photograph the curves with an ordinary dry plate. During an exposure of three minutes the changes in the form, size and position of the illuminated cross-section of the vibrating segment were not such as to ruin the picture.

The behavior of the vibrating cord as a controlling device is such that it seems possible to use it to advantage as a means of obtaining a uniform motion in chronographs and similar instruments. Its length or tension could be adjusted without stopping the apparatus and any desired rate of speed could be thus obtained without interrupting the work which might be in progress.

June 2, 1888.

ART. XXXVII.—*Rhætic Plants from Honduras;* by J. S. NEWBERRY. With Plate VIII.

IN 1886 Mr. Chas. M. Rolker, a mining engineer and graduate of the School of Mines, brought from San Juancito, Honduras, among other geological specimens, a piece of metamorphosed shale containing several impressions of the fronds of cycads. As no Mesozoic fossils had before been found in this region the discovery interested me much and I have since made earnest efforts to obtain other specimens from the same locality. Mr. Rolker kindly seconded these efforts and wrote to Mr. T. H. Leggett, E.M., who was located at San Juancito, giving him all the information he possessed in regard to the locality where the fossils were found, and soliciting his coöperation. This was cordially granted, with interesting results.

The specimen brought by Mr. Rolker was a loose piece picked up on the surface and nearly two years passed before its place of origin was ascertained. In January last I received a letter from Mr. Leggett announcing the discovery of the plant beds and the shipment to me of a box of fossils. These were exhibited at a meeting of the N. Y. Academy of Sciences on Jan. 30, 1888, and were briefly described in the Transactions of the Academy, vol. vii, p. 113. Since that time Mr. Leggett has returned to New York bringing another box of fossils from the same place, among which are some additional species.

From the notes furnished me by Mr. Leggett it appears that the plant beds of San Juancito form part of a series of argillaceous shales now converted into hydromica schists several hundred feet in thickness. Below these, limestones crop out which are said to contain Carboniferous fossils, while above them are heavy masses of eruptive rock. The plant-bearing shales are much disturbed and metamorphosed, and are cut by a series of silver-bearing veins which have been worked for many years with considerable success. The outcrops which contain the plants are much decomposed and few good specimens have been obtained from them, but the number of species represented is large and it is evident that further excavation would result in the accumulation of much interesting material.

The age of the deposit as indicated by its plants is plainly Upper Triassic and the flora as a whole has a great resemblance to that of the coal-bearing strata on the Yaki river in Sonora, Mexico, described by me in the Report of the San Juan Exploring Expedition, and to that described by Schenk in *Die Fossile Flora der Grenzschichten des Keupers und Lias*

Frankens and to Nathorst's *Florau vid Bjuf;* a number of the species being identical and others closely allied.

The localities nearest to Honduras where fossils indicative of Triassic age have been before discovered were in Sonora, Mexico, 2000 miles north, and in the Andes of Peru, where Triassic rocks were found by David Forbes, 2000 miles south. The plants contained in the collection made by Mr. Leggett are here briefly described :

Zamites (*Pterophyllum*) *Rolkeri* Newb. Figs. 1, 2.

Frond a foot or more in length by two inches in width ; rachis chaffy ; pinnules diverging from the midrib at an acute angle, alternate, closely set, attached by the entire breadth of the base to the upper surface of the midrib, which they completely cover ; summit rounded or blunt-pointed ; nerves fine, parallel.

This plant has the general aspect of those described by Heer in the Flora Arctica, vol. iii, Pl. XIV, XV, XVI, under the names of *Zamites speciosus*, *Z. borealis* and *Z. acutipennis*, and should be placed in the same genus. It also still more closely resembles *Pterophyllum Nerbuddaicum* Feistmantel (Flora of the Jabalpur Group, p. 14, Pl. VI, figs. 9, 9*a*), and "*Zamites obtusifolius*" and "*Pterozamites gracilis*" of Emmons (Amer. Geol. Rt., vi, p. 118, 119, figs. 85, 86).

It is evident that all these plants should be separated from *Zamites* if *Z. Feneonis* Brongt. be taken as a type of that genus. And they cannot be included in *Pterophyllum* if, with Schimper and Schenk, who have given us the latest and best classification of fossil cycads, we restrict that name to those in which the pinnules are set at a right angle with the rachis and are connate at their bases. Some writers would put them in *Ctenophyllum* and they are certainly closely allied to the group of cycads typified by *Pterophyllum pecten* of Lindley and Hutton (now *Ctenophyllum*), but have little in common with the gigantic *Ctenophyllum grandifolium* of Fontaine (Older Mesozoic Flora of Virginia), in which the pinnules are set on the side of the rachis, have the bases dilated and are sometimes a foot in length by half an inch in width.

Zamites (*Otozamites*) *Leggetti* Newb. Figs. 3, 4.

Fronds linear, one and a quarter inches in width by eight to ten inches in length ; pinnules alternate, crowded, set on the upper side of the rachis, their bases meeting above, closely approaching below ; in form they are oblong or linear, obliquely rounded above, sometimes slightly rounded at the base ; nerves fine, radiate below, parallel above.

This plant, like the preceding, was briefly characterized in the Transactions of the New York Academy of Sciences, vol. vii, p. 114. It differs from *Z. Rolkeri* in its shorter and broader pinnules and in its nervation, which is partly radiate. Better specimens than any yet obtained are needed before a complete description of it can be written, or its generic relations be accurately determined. Some of the pinnules appear to be attached by the entire base, while in others the attachment is only by the central portion and the nervation is more distinctly radiate. Like the preceding species it is only referred to *Zamites* provisionally, and it is almost certain that they will ultimately be assigned to different genera.

In general aspect this and the preceding species closely resemble *Ptilophyllum acutifolium* and *Pt. Cutchense* Morris, Fossil Flora of India, but are distinctly separated from them by the mode of attachment and the nervation.

It is evident that still another review of fossil cycads is needed although we have had so many already, but this is no place for it and it will be sufficient for our present purpose to refer the plants described above to *Zamites*, as Heer has done those with which I have compared them, leaving their final generic titles to be decided hereafter, by the study of more complete specimens.

Otozamites linguiformis, n. sp. Figs. 9, 10.

Fronds strong; rachis striate; pinnules one to two inches in length by half an inch in width, crowded, sometimes overlapping; below issuing from the rachis at right angles, above obliquely; outline long-tongue-shaped; summits evenly rounded, bases unequally cordate, attached by a single point at the center; nerves numerous, fine, simple or forked, radiating from the center of the base to all parts of the margin.

This handsome species is allied to, though quite distinct from, *Otozamites Macombii* N. from the Upper Triassic rocks of Sonora, Mexico. (Report of the San Juan Expedition, p. 141, Pl. IV, figs. 1, 2). In that species the pinnules are broader, are abruptly rounded or truncated at the summit, and on the lower part of the frond are quadrate; while the corresponding pinnules of the plant now described are oval. Some of the upper pinnules are set obliquely on the rachis, are long-elliptical in outline, slightly curved or sigmoidal, are obliquely rounded at the base and attached by a single point, thus conforming strictly to the definition of *Glossozamites* Schimper, and serving as a connecting link between that genus and *Otozamites.* Whether the rachis in our plant is furrowed as in the type species of *Glossozamites* (*G. Zittelli* Schenk) is not certain, but apparently it is so. Figure 10 represents one of the longer pinnules detached.

Taeniopteris glossopteroides Newb.

Frond simple, six to twelve inches in length by one and a half to two inches in width, spatulate in outline, summit sub-acute, base long-wedge-shaped, the median nerve strong and smooth, the lateral nerves relatively sparse and distinct, frequently forked at base, more rarely above, the branches sometimes approaching, forming elongated areoles but never inosculating.

This species was first obtained from Sonora, Mexico, and was described in the San Juan Report, p. 147, Pl. VIII, fig. 2*a*. By an error of the draughtsman the lateral nerves were represented as inosculating, but recent observation has shown that they do not join. Owing to this error another plant was confounded with this, which strengthened the misapprehension in regard to its nervation. This latter plant is shown in fig. 2 of the plate cited, where it is given a strong midrib, though it had none, unless toward the base; but has a distinctly reticulated nervation. It therefore belongs to Feistmantel's genus *Gangamopteris* and I have called it *G. Americanus*.* The plant I have named *Taeniopteris glossopteroides* is represented by a number of specimens in the collection of Mr. Leggett, but unfortunately owing to the weathering of the rock they do not show the nervation well. The lateral nerves from base to summit leave the midrib at an acute angle, generally arching with a gentle curve to the margin, but sometimes nearly straight. They are often forked near the base, more rarely above, sometimes running near together, but apparently never join. This nervation is just that of *Taeniopteris marantacea* Presl. (*Pecopteris macrophyllum* Brongt., *Stangerites marantacea* Bornem), a plant made the type of his genus *Danaeopsis* by Heer; but in that plant the frond is pinnate, in ours it is symmetrically spatulate, gradually narrowed to the base, and was undoubtedly simple. In all the characters shown in the specimens before me this plant comes nearest to the group of Permian species to which Schimper restricts the name of

* The distinction between *Gangamopteris* and *Glossopteris* is not quite as clear as it might appear from a comparison of the specimens figured and described by Feistmantel in his Flora of the Talchir-Karharbari Beds; the diagnostic character of *Gangamopteris*, the absence of a midrib, being variable, as shown in his *Glossopteris decipiens* (op. cit., p. 17, Pl. XVIII, figs. 3–5), in which the midrib fades out in the upper part of the leaf. This I find also to be true of a number of Australian specimens in my possession. These include many leaves of small size having the spatulate outline and rounded summit of *G. Browniana*, and labeled as such, and others, much larger, of *G. ampla* Dana. Both these forms show a midrib only near the base, and have a nervation but sparingly reticulate, with elongated meshes. Other specimens representing Dana's *G. elongata* and *G. reticulum* (Geol. U. S. Exploring Expedition Atlas, Pl. XIII, figs. 2, 3, 4) have the midrib persistent to the summit and the nervation strongly reticulate throughout. These two forms might stand for *Gangamopteris* and *Glossopteris* if to the former genus a midrib were conceded for part of the length of the frond.

Taeniopteris, viz: *T. multinervis* Weiss, *T. Eckardi* Germ, etc. More and better specimens must, however, be obtained from Honduras before the relations of these plants can be accurately determined.

Encephalartos? denticulatus, n. sp. Fig. 5.

Size of frond unknown, rachis smooth or finely striated longitudinally; pinnules diverging at an angle of about 45°, lanceolate, 30^{mm} long by 6^{mm} wide, acute, gradually narrowed to the point, abruptly narrowed at the base which is attached by its entire breadth; margins set with numerous, spiny teeth; nerves fine, mostly parallel, somewhat radiate from the base and many terminating in the teeth of the margin.

Of this remarkable cycad only a single specimen has yet come into my hands. This is a fragment apparently from the middle of a frond showing three complete pinnules and the bases of two others. Its general characters are well shown in the figure. So far as known this is the first instance of the discovery of a cycad with denticulated pinnules in American Mesozoic rocks, and among foreign cycads only a group of species of *Sphenozamites* have pinnules with toothed margins. It is not uncommon to see this character in living cycads, particularly in *Encephalartos* and *Zamia*. In the latter genus the nerves are parallel and terminate in closely approximated marginal teeth or notches toward the upper extremity. In the former genus, however, forms occur which are almost exactly like those presented by the fossil under consideration, viz: fronds bearing pinnules obliquely inserted, contracted at the base, lanceolate in outline, having fine mostly parallel nerves and margins set with spiny teeth, e. g., *Encephalartos Altensteinii* Lehmann, Cape of Good Hope. This correspondence in the form of the pinnules is so close that I felt warranted in placing our fossil provisionally in the genus *Encephalartos*. The fructification will of course be necessary for a demonstration of generic identity and has not yet been obtained.

Only one fossil species of *Encephalartos* has yet been described and that is *E. Gorceixianus* Saporta, from the Miocene Tertiary of Koumi, Greece. This has lanceolate, acute entire pinnules, two inches long, somewhat constricted at the base and slightly decurrent; nerves parallel. It is supposed to represent an extinct species of *Encephalartos* similar to *E. Lehmani* of South Africa, but the similarity between these fossil species is scarcely as great as between the plant under consideration and *E. Altensteinii* Lehm., with which I have compared it.

Sphenozamites robustus, n. sp. Figs. 12–14.

Frond large, form unknown, pinnules one to four inches in length, ovoid or lanceolate in outline, narrowed and thickened at the base, pointed at summit, margins entire, thickened; nerves few and strong at base, forking and multiplying above, diverging to all parts of the margins, not converging at summit.

Quite a number of pinnules, all more or less imperfect, of this remarkable cycad, are contained in the collection brought by Mr. Leggett from Honduras. They vary considerably in form and size, but present characters which are somewhat at variance with those of any other fossil cycads known, though they most resemble those of some species of *Sphenozamites*. They are distinctly wedge-shaped at base, expanding to an unsymmetrical ovoid or lanceolate outline above with radiate and divergent nerves, which below are few and coarse, above very fine. In the larger pinnules the summit is pointed and in some cases unsymmetrically acute. If, as seems probable, the curvature of the pinnules was toward the summit of the frond the general aspect of the plant may have been much like that of *Sphenozamites Geylerianus* Zigno (Flor. Fos. Oolitica, vol. ii, p. 107, Pl. XXXIX, figs. 1, 2) only it must have been much larger. Fragments of the lower portions of the pinnules are not unlike some of the specimens of *Podozamites latipennis* figured by Heer (Flor. Fos. Arctica, vol. vi, Pl. XIV and XV), but the nerves are not parallel with the margins nor do they converge at the summit.

Among other described fossil cycads none seem to approach so near to the plant before us as the species of *Sphenozamites* with entire pinnules, and here the resemblance is so close that I have felt justified in referring it provisionally to that genus.

Sphenozamites? grandis, n. sp.

Pinnules four inches or more in length, oblong or lanceolate, obtuse, narrowed and thickened toward the base, nerves strong, straight, simple or rarely forked, part diverging from the base to the margins, part running parallel to the upper extremity.

Of this plant we have numerous fragments in the collection, but none of them complete organs. The pinnules were four or five inches in length by an inch in width and are conspicuous for their clear and strong nervation, which is radiate from the base. They undoubtedly represent a large cycad, hitherto undescribed, but it will be necessary to have complete pinnules to decide whether it should be referred to *Sphenozamites*, *Otozamites*, or *Glossozamites*. It must have been much like the plant described by Feistmantel (Foss. Flora of the Lower Gondwanas, p. 19, Pl. XX, figs. 4, 5) under the name of

Glossozamites Stoliczkanus, and should doubtless be included in the same genus, but it seems to me very doubtful whether that should be the same as that for which *G. Zitteli* stands as the type.

Anomozamites elegans, n. sp. Figs. 6–8.

Fronds narrow, elongate, delicate, from half an inch to one inch in width, length unknown; midrib straight and persistent but slender; pinnules near base in close contact, as broad as long, forming a scolloped margin to the midrib; above subquadrate or rhomboid in outline with the lower external angle rounded, the upper subacute, produced; nerves fine, simple or forked, parallel with the upper margin of the pinnules.

Among the fossil plants brought from San Juancito by Mr. Leggett are a number of narrow fronds with subquadrate pinnules which evidently represent the group of cycads which runs through the Mesozoic rocks of Europe, beginning with *A. minus* Brgt. in the Rhætic and ending with *A. Schaumburgensis* Dunker, in the Wealden. It is perhaps most like *A. gracilis* Nathorst (Sveriges Fossila Flora, p. 43, Pl. XII, figs. 4–12), but from this as well as from the other species referred to it is distinguishable by the more pointed and produced upper angles of the pinnules. Figure 6 apparently represents the basal portion, fig. 7, the middle and fig. 8, the summit of these fronds.

Pterophyllum propinquum? Goepp.

Frond large, pinnules subalternate, linear, long-pointed, four inches in length by one-half an inch in breadth at base, gradually narrowed to the acute extremity, springing from the rachis at right angles; base sometimes slightly rounded and narrowed, oftener attached by its entire breadth; nerves distinct, simple, parallel.

The specimens I have of this plant are too few and imperfect to make a comparison with the species described by Goeppert entirely satisfactory. The bases of some of the pinnules seem to be slightly contracted and with a few divergent nerves. If this should be shown by better specimens to be a constant character it would bring this plant into *Zamites* and into close relationship with *Z. Renevieri* Heer, of which the size and general aspect must have been very similar.

Pterophyllum Braunsii? Schenk.

Of this plant one complete pinnule and several fragments are contained in the collection, but are scarcely sufficient for accurate determination. It is evident, however, that we have here the remains of a species of *Pterophyllum* or *Nilssonia* remark-

ably like, if not identical with that described by Schenk (Flora der Grenzschicten, p. 168, Pl. XL, figs. 2, 3) under the name of *Pterophyllum Braunsii.* The pinnules were attached by the entire base, are an inch in width by two and a half inches in length, the summit is obliquely rounded, the nervation fine, parallel and simple, sometimes dotted as shown in Schenk's figure.

A nearly related plant to this is *Pt. princeps* Oldham and Morris (Fossil Flora of the Rajamahal Series, p. 23, Pl. X–XIII), but our material is too imperfect for the determination of specific identity or difference.

Dioonites longifolius? Emmons.

An imperfectly preserved fragment from the middle of a frond is all we have of a plant that if not identical with must have been very closely allied to that described by Emmons (Amer. Geol., Part VI, p. 116, fig. 83) from the Upper Triassic strata of North Carolina.

Dioonites Carnallianus? Goepp.

This plant is imperfectly shown in the collection made by Mr. Leggett, but is plainly distinct from any other with which it is associated. It evidently belongs to a group of cycads which form a marked feature in the Rhætic flora and of which *Pterophyllum Carnallianum* of Goeppert may be taken as a type. In this group the fronds are broad, the pinnules very long and narrow, attached to the rachis by the entire bases, which are sometimes slightly decurrent, but never expanded upward nor connate; the nerves are sharply defined, but fine, simple and parallel.

More material will be required before the identity of the Honduras plant with that to which it is provisionally referred can be asserted. It is, however, a distinct element in the San Juancito flora and deserves mention from its relationship with the group of Rhætic cycads with which I have compared it.

Nilssonia polymorpha Nathorst.

Only a few fragments of this plant are contained in the collection made by Mr. Leggett, but these are quite sufficient to show its distinctness from any other with which it is associated and to determine its generic relations. Whether the segments of the frond were united, as is usual in *N. polymorpha*, can only be determined from other collections, but this is not indicated by the specimens before us; the pinnules being entirely distinct and separated.

Fragments of the species of *Anomozamites* found with this might at first sight be confounded with it, but in these the

divisions of the frond are not carried down to the rachis and the nervation is much finer. A similar and perhaps an identical species of *Nilssonia* occurs in the Triassic coal basin of Sonora, Mexico.

Nöggerathiopsis, sp.

Among the fossil plants from Honduras, as well as those collected by Remond in Sonora, are some which perhaps represent different genera, certainly different species, but which are alike in having spatulate or wedge-shaped leaves several inches long, traversed by a fine or coarse parallel nervation. Part of these undoubtedly belong to the genus *Nöggerathiopsis* so common in the Mesozoic rocks of Australia and India, but they are too imperfect to be satisfactorily identified or described. Some of them must have been a foot or more in length, and they differ considerably in shape, either expanding rapidly or being long and strap like. The nervation is sometimes so fine as scarcely to be visible, in other cases very coarse, but exact.

Several ferns are contained in the collection, but the specimens are too much weathered and decayed to permit of their identification or satisfactory study. All these, with many other things of which only fragments have been obtained by Mr. Leggett, will doubtless receive attention and elucidation from those who hereafter may have an opportunity of studying the rich flora which it is the object of this paper to bring to the notice of geologists.

This discovery of a Triassic flora in Honduras is a matter of special interest, as nothing of the kind had before been met with in that section of the globe; but it is only another illustration of the uniformity of the vegetation of the world during the Triassic age. This uniformity was, however, only a development of the systematic progress of plant life. The reign of Acrogens ended with the Permian. The Rhætic epoch was therefore about the middle of the reign of Gymnosperms. No Angiosperms were yet in existence, for they began in the Cretaceous. Hence, after the decadence of the *Lepidodendra*, *Sigillariæ*, *Calamites* and *Cordaites*, the whole world was opened to occupation by the new dynasty of plants, the Gymnosperms (Cycads and Conifers) and the peculiar group of Mesozoic ferns. They lost no time in entering upon their promised land and spread until they covered all portions of the, to them, habitable globe.

Where the Gymnospermous flora originated, or how it was developed from the Acrogens, if it was so developed, and through the exercise of what elements of superiority it superseded them, we are as yet in ignorance. It is, however,

a matter that may well excite our wonder that, migrating such immense distances from their places of origin, through every phase of soil and climate—through all the zones of the Eastern Hemisphere, and now, as we learn from this group of Honduras plants, through the New World—they marched, holding so firmly to their original group of characters, generic and specific, that wherever we open their tombs we recognize them instantly as old friends. In their long marches some perished by the way, and here and there their numbers were recruited by new forms, imported or developed; but the leading members of the troop, in virtue of some occult protection against outside influences, preserved almost without alteration all the complicated characters of their vegetative and reproductive systems.

We shall look now with eagerness to South America for the identification there of this Mesozoic flora, which we have found in full development in Virginia, New Mexico, Sonora, and now in Honduras. It had before been recognized in Australia—where it seems to emerge from the Paleozoic flora and perhaps began—New Zealand, India, Tonquin, China, Turkestan, and various parts of Europe.

Hence, with its discovery in South America we shall see it reaching as a girdle around the entire globe. This girdle was not put around the earth, however, like Puck's, in forty minutes, but in thousands and millions of years; for when we realize with what slowness the migration of plants takes place, we must recognize in the universal distribution of the Carboniferous and Mesozoic floras evidence of the lapse of intervals of time of which the duration is simply immeasurable to us.

ART. XXXVIII.—*On the Circular Polarization of certain Tartrate Solutions.* I. By J. H. LONG.

THE change in the circular polarization of a solution of an active substance by admixture with an inactive one has been studied in several cases. Müntz found, for instance, that the specific rotation of cane sugar for a concentration of 20^{gm} in 100^{cc} changed from $[\alpha]_D = 66\cdot^{\circ}5$ to $[\alpha]_D = 66\cdot^{\circ}3$ by addition of 5^{gm} of NaCl, and to $61\cdot^{\circ}0$ by addition of $20^{m.g}$

The same chemist and others have shown the effects of adding various substances to sugar solutions. In most cases a decrease in the specific rotation was found.

Under certain circumstances the addition of an inorganic substance converts an inactive organic body into an active one, as in the case of mannite when in solution with alkalies, weak

acids and several neutral salts. Under still other circumstances the rotation of an active body can be very greatly increased by the addition of certain inactive ones, as is well illustrated by Gernez (*Berichte der Deutschen Chem. Gesell.*, xx, Ref. 251), in his experiments on mixtures of tartrates with molybdates, arsenates, tungstates, etc. He found, for instance, that the addition of $NH_4\ MoO_4$ to a solution of tartaric acid increased its rotation about fifty times.

This subject is one of great practical interest as well as of scientific importance, and it seemed to me that further investigation on the rotation of the tartrates must yield results of some value.

The following pages discuss results obtained with solutions of Rochelle salt in an investigation begun above a year ago and which is still in progress.*

Apparatus and methods.

In my experiments I employed a new model Laurent instrument made by Schmidt & Haensch, and used with this polarization tubes 200 and 220^{mm} in length, surrounded by a water jacket. The tubes were carefully measured and were found to differ so slightly from the given length (less than ·05^{mm}), that I employ the whole numbers instead of introducing a fraction in the calculations. By means of suitable appliances the temperature of the solutions under examination was kept within 0°·2 of 20°, as shown by a delicate thermometer. In most cases, however, this extreme accuracy in the control of the temperature was not necessary as the variations caused by change of temperature were very small. In each test a dozen or more readings were made for each position of the analyzing Nicol, and on the two verniers 180° apart. The instrumental error was almost inappreciable to begin with, and disappeared entirely by taking a mean of all the readings.

At a temperature of 20° a solution of tartaric acid containing 15^{gm} in 100^{cc} showed a specific rotation $[\alpha]_D = 13°·03$. This is diminished when the solution contains free mineral acids, and is also much diminished when certain neutral salts are added. With a solution containing 15^{gm} of tartaric acid and 8^{gm} of sodium chloride I found the specific rotation less than one-half as much as before, viz: $[\alpha]_D = 6°·16$.

If instead of starting with tartaric acid a neutral tartrate be taken and various salts added quite different results are obtained. In the first place, the change in the specific rotation is much less than when the acid is used, and besides this the na-

* This investigation was begun before the work of Gernez came to my notice, and before the publication of recent papers by Landolt (Berichte, 1888, p. 191), in which reference is made to the behavior of certain tartrates. A second paper will deal with other tartrate solutions.

ture and amount of the change is characteristic of certain groups of salts. These points are shown below.

At the outset I prepared a quantity of pure Rochelle salt, sufficient for all experiments contemplated, and determined the rotation with five solutions containing exactly 5, 15, 25, 35 and 45gm in 100cc, measured at 20° C.

The results of these tests are given in the table, the specific rotation being calculated from the formula,

$$[a] = \frac{10^4\ a}{\mathrm{L.\,C.}},$$

in which a is the observed angle of rotation, L the length of the tube containing the solution in millimeters, and C the concentration of the solution, that is, the number of grams in 100cc.

T	L	C	Sp. Gr. $(\frac{20}{4})$	a	$[a]$
20°	200mm	5	1·0261	2°·214	22°·14
20°	200mm	15	1·0739	6°·650	22°·16
20°	200mm	25	1·1202	11°·058	22°·12
20°	200mm	35	1·1655	15°·493	22°·13
20°	200mm	45	1·2100	19°·854	22°·06

The specific rotation appears to be practically constant with the varying concentration, and the change in the angle of rotation by variation of temperature is inappreciable as I found by observing several of the solutions when heated to 35°. Krecke found (*Arch. Néerland.*, vii, 202), with a Rochelle salt solution containing 20gm in 100cc, the specific rotation $[a]_D = 22°·42$ at 25° C. For a solution containing 10·771gm of the anhydrous salt in 100cc Landolt found (*Berichte*, vi, 1073), $[a]_D = 29°·67$, which is equivalent to 22°·09 for the crystals.

This is practically the same as I obtained in the table above, and as I found it in numerous other tests carefully conducted I am inclined to think it is the true specific rotation. In what follows I will take 22°·1 as the constant at 20°.

For each one of the following tests I took 20gm of the Rochelle salt and dissolved it in a narrow-necked flask graduated to hold 100cc at 20°. Then the amount of the inactive salt was added and water enough to nearly reach the mark. After shaking, the flask was brought to the right temperature by suspending it in a large vessel of water kept at 20°. A little distilled water having the same temperature was added and this was continued, until, after shaking, the mark was just reached. The limit of error here is about one-twentieth of one per cent.

The solutions so made were then used in the polariscope. In all the experiments here given the temperature was kept at 20° and the 200mm tube was employed.

The following table embraces the results obtained:

Formula and amount of inactive salt added to 20gm. of $KNa\ C_4H_4O_6.4H_2O$ in 100cc.	Observed rotation a	Specific rotation $[a]$	Deviation from Normal.
NaCl 5gm	8°·719	21°·80	—°·30
NaCl 10	8·483	21·21	— ·89
NaCl 15	8·218	20·54	—1·56
NaCl 20	7·900	19·75	—2·35
NaBr 5	8·757	21·89	— ·21
NaBr 10	8·668	21·67	— ·43
NaBr 15	8·558	21·40	— ·70
NaBr 20	8·440	21·10	—1·00
Na_2SO_4 (anhyd.) 5	8·669	21·67	— ·43
Na_2SO_4 10	8·526	21·32	— ·78
Na_2SO_4 15	8·376	20·94	—1·16
Na_2SO_4 20	8·200	20·50	—1·60
$NaNO_3$ 5	8·688	21·72	— ·38
$NaNO_3$ 10	8·604	21·51	— ·59
$NaNO_3$ 15	8·514	21·29	— ·81
$NaNO_3$ 20	8·426	21·07	—1·03
$Na_2HPO_4 . 12H_2O$ 5	8·765	21·91	— ·19
$Na_2HPO_4 . 12H_2O$ 10	8·721	21·80	— ·30
$Na_2HPO_4 . 12H_2O$ 15	8·675	21·69	— ·41
$Na_2HPO_4 . 12H_2O$ 20	8·630	21·58	— ·52
$Na_2S_2O_3 . 5H_2O$ 5	8·744	21·86	— ·24
$Na_2S_2O_3 . 5H_2O$ 10	8·611	21·53	— ·57
$Na_2S_2O_3 . 5H_2O$ 15	8·497	21·24	— ·86
$Na_2S_2O_3 . 5H_2O$ 20	8·365	20·91	—1·19
$NaH_2PO_2 . H_2O$ 5	8·761	21·90	— ·20
$NaH_2PO_2 . H_2O$ 10	8·575	21·44	— ·66
$NaH_2PO_2 . H_2O$ 15	8·360	20·90	—1·20
$NaH_2PO_2 . H_2O$ 20	8·127	20·32	—1·78
$NaC_2H_3O_2 . 3H_2O$ 5	8·782	21·95	— ·15
$NaC_2H_3O_2 . 3H_2O$ 10	8·681	21·70	— ·40
$NaC_2H_3O_2 . 3H_2O$ 15	8·566	21·41	— ·69
$NaC_2H_3O_2 . 3H_2O$ 20	8·450	21·12	— ·98
$Na_2B_4O_7 . 10H_2O$ 10	8·729	21·82	— ·28
Na_2WO_4 (anhyd.) 10	8·276	20·69	—1·41
LiCl (anhyd.) 6·752	8·172	20·43	—1·67
Tl_2SO_4 5	7·469	18·67	—3·43
KCl 5	9·088	22·72	+ ·62
KCl 10	9·140	22·85	+ ·75
KCl 15	9·228	23·07	+ ·97
KCl 20	9·372	23·43	+1.33
KBr 5	9·087	22·72	+ ·62
KBr 10	9·123	22·81	+ ·71
KBr 15	9·172	22·93	+ ·83
KBr 20	9·244	23·11	+1·01
KI 5	8·918	22·29	+ ·19
KI 10	9·025	22·56	+ ·46
KI 15	9·105	22·76	+ ·66
KI 20	9·182	22·95	+ ·85
KNO_3 5	8·986	22·46	+ ·36
KNO_3 10	9·104	22·76	+ ·66
KNO_3 15	9·239	23·10	+1·00
KNO_3 20	9·387	23·47	+1·37

Formula and amount of inactive salt added to 20gm. of $KNa\ C_4H_4O_6.4H_2O$ in 100cc.		Observed rotation a	Specific rotation $[a]$	Deviation from Normal.
KSCy	5	8·994	22·48	+ ·38
KSCy	10	9·030	22·58	+ ·48
KSCy	15	9·075	22·69	+ ·59
KSCy	20	9·134	22·83	+ ·73
$KC_2H_3O_2$	5	9·008	22·52	+ ·42
$KC_2H_3O_2$	10	9·093	22·73	+ ·63
$KC_2H_3O_2$	15	9·160	22 90	+ ·80
$KC_2H_3O_2$	20	9·248	23·12	+1·02
K_2SO_4	5	9·040	22·60	+ ·50
K_2SO_4	10	9·094	22·73	+ ·63
$K_2C_2O_4 . H_2O$	5	9·030	22·57	+ ·47
NH_4Cl	5	9·033	22·58	+ ·48
NH_4Cl	20	9·239	23·10	+1·00
NH_4Br	5	8·987	22·47	+ ·37
NH_4Br	15	9·093	22·73	+ ·63
$(NH_4)_2C_2O_4 . H_2O$	5	9·004	22·51	+ ·41
NH_4SCy	10	9·036	22·59	+ ·49

A simple inspection of the table shows immediately several important points. The addition of the sodium salts, without exception, causes a decrease in the rotation, which is greater as the amount of inactive salt is increased. The behavior of the thallium salt is interesting; here a remarkable change is produced. Experiments now in progress promise to throw some light on the action of thallium compounds in parallel cases. The addition of potassium and ammonium salts, without exception, increases the specific rotation. This deviation becomes greater as more of the inactive salt is added. We have here a remarkable difference between the sodium, thallium and lithium compounds on the one hand and the potassium and ammonium compounds on the other. These peculiarities may sometimes be applied in the quantitative analysis of salt mixtures. These characteristic points and the amount of variation can be most conveniently shown by curves in which the abscissas are the amounts of inactive substance in solution with 20^{gm} of Rochelle salt and the ordinates the specific rotation of the mixture, or better, the deviation of this from a simple water solution of the tartrate.

I have drawn the curves given in fig. 1 on this plan. It will be observed that some of them are practically straight lines which can be represented by a simple equation of the form

$$[a] = (a)_0 + Ag,$$

in which g is the amount of inactive substance in solution, and $(a)_0$ the calculated rotation when $g = 0$. It might appear that this value should be the same as that observed for the pure tartrate solution, but I think that does not necessarily follow.

In the other cases the observations lead to a curve as expressed by

$$[\alpha] = (\alpha)_0 + Ag + Bg^2,$$

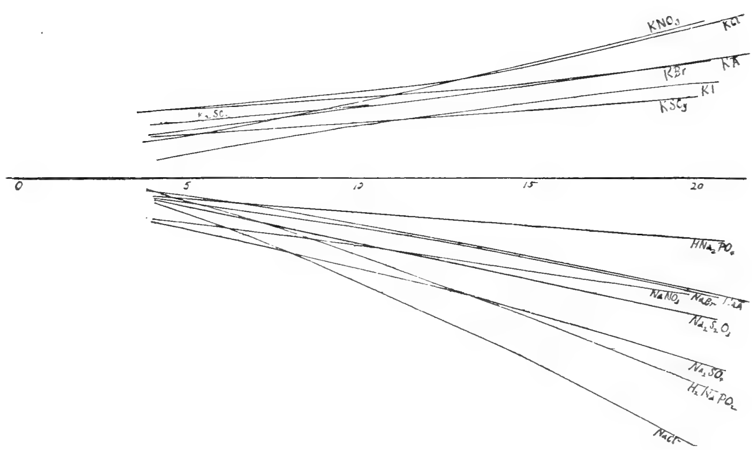
in which the letters have the same meaning as before.

From the first three solutions containing potassium nitrate I have calculated according to this

$$[\alpha] = 22\cdot^\circ 20 + 0\cdot 048g + 0\cdot 0008g^2.$$

I have not thought it necessary to find an interpolation formula for all the solutions. It is evident from an inspection of the curves that they intersect the base line at $g = 0$ only in a few instances, and the deviations are usually greater than could be referred to errors of observation.

1.



As mentioned above, the addition of a potassium salt increases the rotation while sodium salts diminish it. The numbers as given seem to show no relation beyond this. However, if instead of giving the rotation for solutions containing equal weights of active and inactive substance, they be calculated for equal numbers of molecules in solution the results obtained show certain regularities which must be more than accidental. These desired values can be obtained readily and accurately by graphic interpolation and in the following table they were so derived.

[α], *When for* 1 *molecule of tartrate* 1, 2 *or* 3 *molecules of inactive substance are present.*

Formula of salt.	1 mol.	2 mol.	3 mol.	
$NaCl$	21·86	21·41	20·99	
$NaBr$	21·79	21·42		
$NaNO_3$	21·68	21.41	21·16	
Na_2SO_4	21·32	20·49		
$Na_2HPO_4 . 12H_2O$	21·40			
$Na_2S_2O_3 . 5H_2O$	21·07			(For ½ mol. = 21·61)
$NaH_2PO_2 . H_2O$	21·67	20·92		(For 1½ mol. = 21·41)
$NaC_2H_3O_2 . 3H_2O$	21·72	21·16		
KCl	22·73	22·88	23·14	
KBr	22·78	23·00		
KI	22·63	23·09		
KNO_3	22·60	23·07		
$KSCy$	22·52	22·66	22·82	
$KC_2H_3O_2$	22·60	22·87	23·25	
K_2SO_4	22·79			
NH_4Cl	22·54	22·67	22·81	
NH_4Br	22·54	22·70		

We see from the above that the specific rotation in presence of two molecules of $NaCl$, $NaBr$, $NaNO_3$, or one molecule of $Na_2HPO_4 . 12H_2O$, or one and one-half molecules of $NaH_2PO_2 . H_2O$ is very nearly the same, 21·°41.

In presence of one molecule of Na_2SO_4 it is a little less, while for $NaC_2H_3O_2$ and $Na_2S_2O_3$ no simple relation is apparent.

Two molecules of KBr, KCl, KI, KNO_3 and $KC_2H_3O_2$ exert nearly the same influence, one molecule of K_2SO_4 gives a smaller value, while $KSCy$ is irregular.

Roughly, it appears that the potassium salt molecules increase the rotation in about the same proportion that the sodium salts diminish it. The explanation of this may not be immediately apparent.

Cases similar to those observed in the experiments of Gernez, referred to above, have been explained by the hypothesis of Biot according to which loose combinations are formed between the active and inactive substance having a rotation different from that of the former. Gernez has given the composition of some of these molecular combinations. The case in hand, however, is somewhat different. If we could assume here an action of mass by which on addition of potassium salts the solution would be made to contain neutral potassium tartrate, and on addition of sodium salts neutral sodium tartrate, then the disturbance could be partially explained. According to Landolt (*Ber.*, vi, 1073), the specific rotation of neutral potassium tartrate, calculated as anhydrous, is 28·48, while that of the neutral sodium salt is 30·85. However, if instead of taking equal

weights as our basis we take equal numbers of molecules, we obtain the following values representing the *molecular rotation* of the three salts,

$$K_2C_4H_4O_6 = 64{\cdot}42$$
$$KNaC_4H_4O_6 = 62{\cdot}34$$
$$Na_2C_4H_4O_6 = 59{\cdot}85$$

from which it is apparent that the conversion of 20^{gm} of Rochelle salt into the neutral potassium tartrate would give a solution with increased rotation, while conversion into sodium tartrate would give a solution with diminished rotation. On this assumption the change can be accounted for in part, but only in part. Taking the rotation for the mixture of 20^{gm} of $KNaC_4H_4O_6 . 4H_2O$ with 20^{gm} of KCl, given in the table above, we have $\alpha = 9^\circ{\cdot}372$. Now, considering this as produced by $16{\cdot}03^{gm}$ of $K_2C_4H_4O_6$—the equivalent of 20^{gm} of $KNaC_4H_4O_6 . 4H_2O$—we obtain a specific rotation,

$$[\alpha] = 29^\circ{\cdot}23,$$

which is too much, Landolt's value being 28·48.

In the same way taking the rotation $\alpha = 7^\circ{\cdot}900$ found for the solution containing 20^{gm} of $KNaC_4H_4O_6 . 4H_2O$ and 20^{gm} of NaCl and supposing this rotation produced by $13{\cdot}76^{gm}$ of $Na_2C_4H_4O_6$ we find the specific rotation,

$$[\alpha] = 28{\cdot}70,$$

which is too low, or, in other words, *too great a reduction*, Landolt's value being 30·85.

It will be seen, however, that the rotations found for the mixtures of the tartrate with the equivalent of two molecules of the simpler inactive salts give numbers which agree with Landolt's values. This is probably more than a mere coincidence. I am at present making a somewhat closer study of it.

The above mentioned hypothesis, while not adequate to explain fully the difference in behavior between the inactive salts added to the tartrate, is still worthy of consideration, I think. In the further progress of the work I shall test it fully. The phenomenon is evidently a complex one and a study of the behavior of other double tartrates must be made before it can be thoroughly understood.

Preliminary experiments indicate that the double tartrates containing thallium or antimony will well repay investigation. The necessary material for such a study is now in course of preparation by an assistant in my laboratory, and with this I hope to be able to throw more light on the subject.

Chicago, July 18th, 1888.

ART. XXXIX.—*Energy and Vision*;* by S. P. LANGLEY.

WHILE it is quite a familiar fact that the luminosity of any spectral ray increases proportionately to the heat in this ray, and indeed is but another manifestation of the same energy, I have recently had occasion to notice that there is, on the part of some physicists, a failure to recognize how totally different optical effects may be produced by one and the same amount of energy according to the wave-length in which this energy is exhibited.

I should not perhaps have thought it advisable to make this last remark, were it not that there has appeared in a recent number of Wiedemann's Annalen, a paper by H. F. Weber on "The Emission of Light," in which he tacitly makes the assumption that the luminosity of a color is proportionate to the energy which produces it, an assumption which it is surprising to find in a paper of such general merit and interest.

In another article of the same number of the journal, the mistake was pointed out by Professor F. Stenger, who remarked that Mr. Weber's assumption was inconsistent with the investigations of the present writer. Still the fact that there could be such a misapprehension at the present day, led me to look at the matter again, and to observe, with some surprise, that there was nowhere, in any physical work known to me, any exact or even approximately exact statement of the relative ocular effects of a given amount of energy in different parts of the spectrum. I have undertaken therefore during the last few months an experimental re-investigation of this subject, with such a statement especially in view.

We shall evidently need two correlated sets of experiments, the first set to determine the amount of energy in each ray, the second to show the corresponding visual effect.

For the first of these, since energy only shows itself through absorptive media which more or less disguise it, we must select that manifestation which disguises it least, and in this respect beyond comparison the thermal one stands first, as the *heat* dispersed by a glass prism and shown by a thickly lampblacked thermometric apparatus is, throughout the visible spectrum, very nearly proportionate to the energy itself. For these first or thermal experiments, whence the energy is readily deduced, with close approximation, we shall rely principally upon a very elaborate investigation made here some time since and already published, where the bolometer is used to deduce in terms of lampblack absorption the relative amounts of solar energy in

* Read by abstract before National Academy of Sciences, April 19, 1888.

various wave-lengths throughout the visible spectrum and a little beyond; and which has been supplemented by a new investigation of the same kind in the present connection.

Our second set of experiments will consist of a recent parallel series of photometric solar measures taken at the same wave-lengths as the thermal ones, and which we may say gives this energy in terms of what I may perhaps be allowed to call, provisionally, "retinal" absòrption.

The thickly lamp-blacked surface, then, and the retinal screen provided by nature in the eye, both exercise selective absorption, but the first whose absolute absorption is here nearly total does so in relatively so small a degree, that we may, in the visible spectrum, provisionally neglect it, and consider the bolometric effect as here proportional to the energy itself.

It is evident that these two series once made, and reduced in both cases to the normal spectrum, would give us for any individual human eye the means of stating the visual effect in terms of absolute energy. The visual effect is known to vary in a very minute degree with the absolute amount of this energy, at least if we admit the physiological influence of what has been called "the color of brightness," but for the comparatively feeble lights employed, this physiological effect seems to be almost negligible, and it is nearly immaterial within the limits of the experiment what unit of energy we take.

The object of these experiments, then, is to take some one constant amount of energy, to actually or virtually display it successively in different portions of the spectrum, and to observe in what proportion the optical or visual effects of this fixed amount of energy vary, according to the wave-length in which it is conveyed. While the measurements which insure this constancy are best made by thermal methods, and while the prism is on the whole far more convenient for them than the grating, it is nevertheless desirable to reduce the whole measurements to what they would have been, if taken directly in the normal spectrum. The writer's measurements, already published and here cited later, afford the means of doing this with precision. These show that the energy is far from being distributed equally even in the normal spectrum; and that, accordingly as it varies from one part of the spectrum to another, we must, by opening the aperture through which it is admitted where it is weak, and by narrowing it where the energy is strong, or by other like device, maintain it absolutely constant, or else (what is far better) let it enter through one fixed aperture, and use the subjoined table to apply a correction for the actual irregularities. Let it be remembered that we are now speaking of absolute energy, not of those physiological effects of it on the organ of vision which we call light, and it is

to the value of this absolute energy for different wave-lengths in the normal spectrum which the subjoined table refers. This table, which gives the energy as derived from thermal experiments, rests on many thousand observations, taken, however, all with what is called a high sun, *i. e.*, with a sun more than 30° above the horizon. As the distribution of this energy varies somewhat from day to day, and particularly in the violet and beyond, we have supplemented it by a series of direct observations taken with the bolometer on April 6, 1888, using the same glass prism employed in the photometric work described later. As those observations show a fair accordance with the others, it is not necessary to repeat them.

TABLE I. NORMAL SPECTRUM.

$\lambda=0^{\mu}\cdot35$	$0^{\mu}\cdot38$	$0^{\mu}\cdot40$	$0^{\mu}\cdot45$	$0^{\mu}\cdot50$	$0^{\mu}\cdot55$	$0^{\mu}\cdot60$	$0^{\mu}\cdot65$	$0^{\mu}\cdot70$	$0^{\mu}\cdot75$	$0^{\mu}\cdot768$
Heat= 1·8	3·7	5·3	11·9	17·3	20·7	21·9	22·2	21·4	20·7	20·2

What has just been given in table I refers to the distribution of energy in terms of lamp-black absorption, *i. e.*, as "*heat.*" We now proceed to attempt to find it in terms of retinal absorption, *i. e.*, as "*light.*" It is well known that color photometry offers peculiar difficulties. My own experience, after a long employment of the Rumford photometer for comparing the relative intensity of different colored lights, is most unfavorable to it, and I have also tried the Bunsen photometer with almost equally unsatisfactory results. I have also experimented with the ingenious photometer described by Masson (Ann. de Ch. et de Ph., ser. III, xiv, p. 129), in which a disk of paper, marked with black and white sectors, is revolved with such rapidity that it assumes a uniform tint when viewed by the colored light in question, but when illuminated by the electric flash displays the sectors again. It is evident that the reappearance of the sectors under the flash will be conditioned by the nature of the light which furnishes the steady illumination. But though on trial this has seemed to yield better results than the ordinary photometers, the method is of difficult application in connection with the particular apparatus about to be described. I have therefore, after considerable experiment, decided in favor of what may seem, at first, to be a cruder method, but which is, I believe, for the present purpose, preferable to any of the foregoing; I mean the determination of the intensity of light necessary to read a table of logarithms or to discern any arbitrary characters.

Description of the Apparatus.

The measures have all been made in a dark room from which every source of outside light is excluded except that which enters the slit of the spectroscope.

The light from the siderostat mirror, M (fig. 1) passes through a small aperture in the north wall and falls on the slit (s_1), (which has doubly moving jaws, 34^{mm} high, set in these experiments at a standard distance of $0{\cdot}1^{mm}$), then on the great collimating lens (l) of 755^{cm} focus (aperture $11{\cdot}9^{cm}$), t_1 being a paper tube to prevent the lateral diffusion of light from dust particles. p is a glass prism,* m, the concave mirror of 148^{cm} focus, which here forms upon a second slit (s_2) a spectrum about 7^{mm} high and 90^{mm} long in the easily visible part from A to H. The prism and mirror are mounted on the spectro-bolometer already elsewhere described,† and which is provided with a circle reading to 10″ of arc. By setting this circle, any color can be brought on the slit (s_2). The light which the mirror has converged into that part of the spectrum overlying this slit passes through it, diverges and falls upon a black paper, figure 2, in which is a central aperture 1^{cm} square, occupied by part of a table of logarithms, printed in small black type on white paper. This table can be adjusted to bring different figures in view, but is otherwise fixed relatively to the black paper screen which (with this central centimeter occupied by figures) is mounted on a slider. The rod (r) on which the slider moves is a prolongation of the spectroscope arm, made of a light wooden rod graduated so that one can read the position of the slider to a centimeter by *feeling* of notches in the dark. The zero of this rod is at slit 2 on which the spectrum is thrown.

It is to be observed that it is necessary that the square of figures should be small in order that it may be slid nearly to the apex of the cone of light and remain covered thereby.

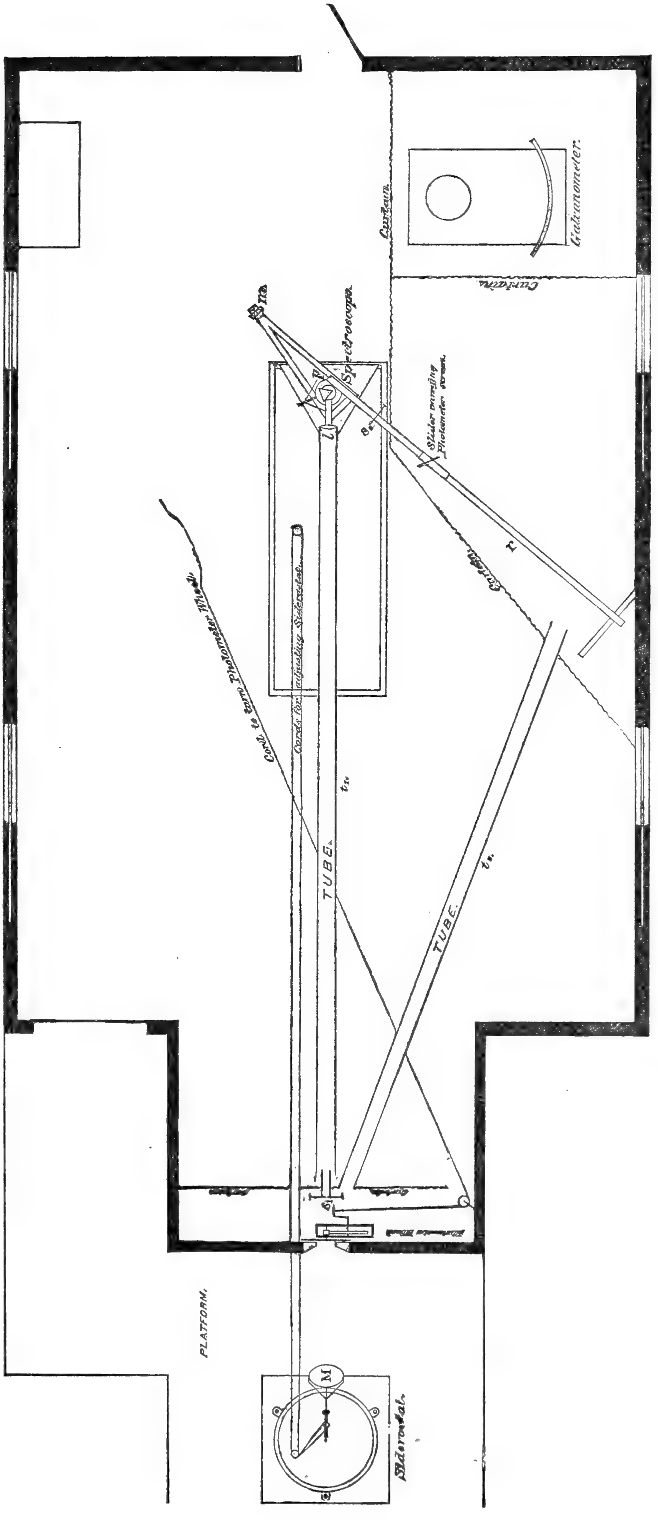
It is to be noted also that at a constant distance and in a feeble light, these small figures may be invisible to the naked eye and most distinctly visible to the same eye with a magnifying glass. For two eyes of different foci, the amount of light with which the same figures will be read will probably vary. It follows that even if the same person read from beginning to end of the series, his readings will not be com-

* Its principal constants are: height of face $11{\cdot}5^{cm}$, width, $10{\cdot}5^{cm}$, while for a temperature of 28° C. the refracting angle is 60° 06′ 45″, deviation

H = 46° 45′ 35″
b_1 = 44 45 55
D_2 = 44 11 15
A = 43 24 05
ω_2 ("little Omega") = 41 34.

† "Researches on Solar Heat," Prof. Papers of the Sig. Serv., No. 15, p. 130.

1.

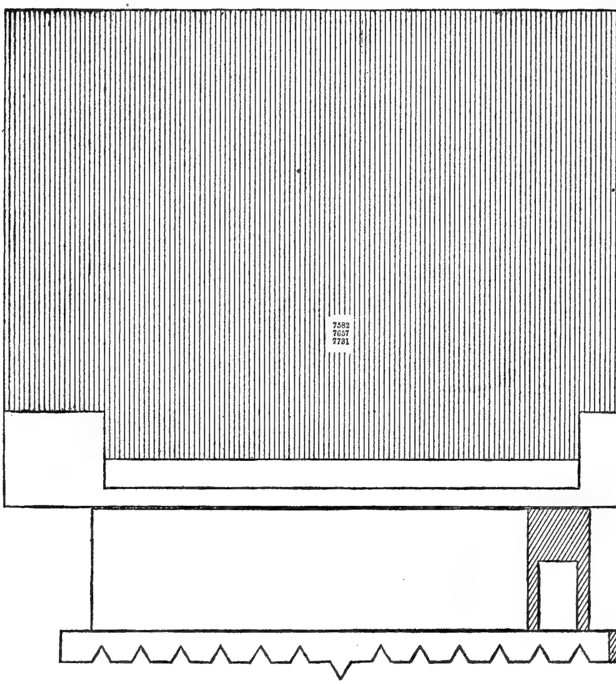


PLAN OF DARK-ROOM.

parable unless they are all taken under the same optical conditions, e. g. all with the naked eye or all with glasses of a certain strength.

In these measurements a magnifying glass of 4·7^{cm} focus was used by all the observers, and in addition, two who were near-sighted wore spectacles correcting this defect.

2.



Screen, one-half size.

The observer, in a room completely darkened, except for the minute light diffused from the particles in the reflected beam, and himself shielded even from the feeble light diffused from the surfaces of the lens, the prism, and the mirror, by the thick black curtain shown on the plan, waited until his eye had become quite sensitive before making the readings. An assistant outside the curtain set the circle by the aid of a dark lantern, and adjusted the siderostat from time to time so as to keep the light exactly on the center of the lens and prism face. The passage of the slightest wisp of cirrus cloud was noted and the observer warned.

Although the light diverges from slit 2 and not from a point, the "cone of rays," above referred to, is, as regards the

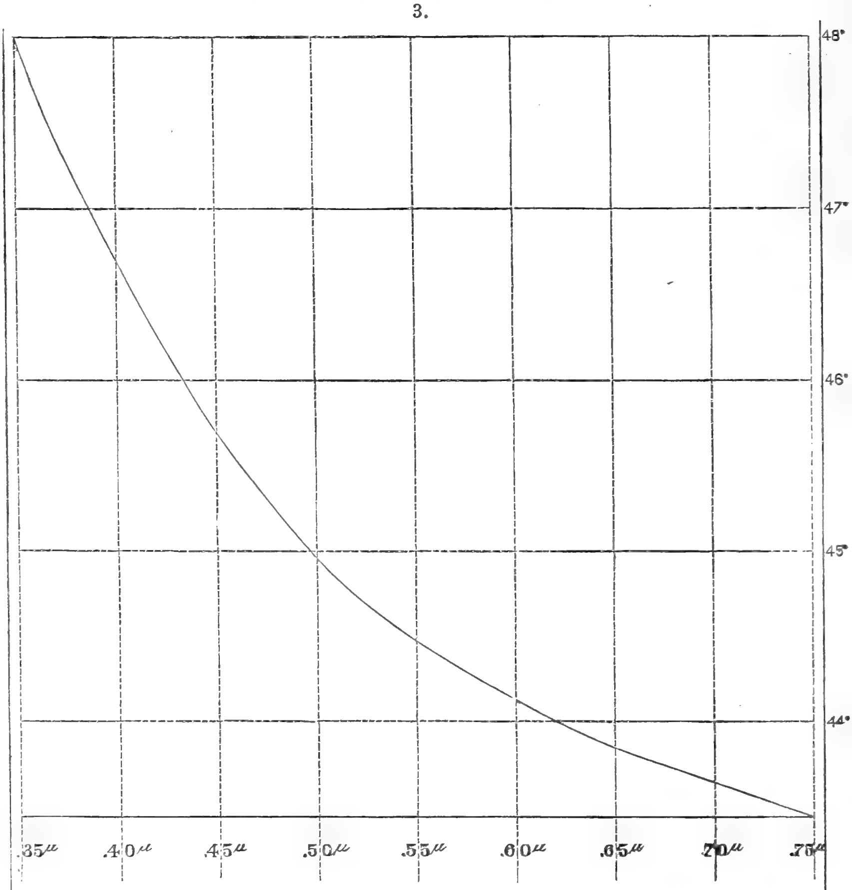
object and limits of our experiments and the limiting positions of the screen, so nearly coincident with a geometrical cone, that, as the slider is carried away from the slit, the light may be treated as diminishing proportionally to the inverse square of the distance from the slit to the screen. The nearest position of the screen brings it within 20^{cm} of the slit, the farthest is over 300, so that we have the power of diminishing the light over $\left(\frac{300}{20}\right)^2$ or over 225 times. This however is by no means a sufficient range for the comparison of the light in the yellow green with that in the extreme red; and because the graduated rod was not long enough to thus give the desired range, a photometer wheel was introduced in some of the measures between the siderostat mirror and the remote slit (s_1). This photometer wheel is capable of reducing the light from ·50 to ·05 or further, and is more fully described in Memoirs National Academy of Sciences, vol. iii, Memoir on the Temperature of the Moon. We have, then, without altering the slit, a range of adjustment through over $\frac{\cdot 225}{\cdot 05}$ or over 4500 times. The slit s_1 where the light first enters has doubly moving jaws, controlled by a micrometer screw. Its standard opening in these experiments for light comprised between $\lambda = 0^{\mu}\cdot 40$ (violet) and $\lambda = 0^{\mu}\cdot 65$ (red) was $0\cdot 1^{mm}$, but it has been opened for supplementary experiments to 5^{mm}, so that we have by opening or closing it a range of light from 50 to 1. It was, however, constantly kept at the standard opening of $0\cdot 1^{mm}$ until the main series of experiments was completed, so as not to vary the light by attempting to reset it by the screw. Admitting, however, that for any given prism, transmitting any given ray, the light is sensibly proportional to the width of the slit (which may vary from 50 to 1), to the disposition of that coming through the photometer wheel, which may vary from 20 to 1, and to the inverse square of the distance of the slider from slit s_2 (225 to 1), we have a possible range of $50 \times 20 \times 225 = 225{,}000$ to 1. This, however, it will be understood, has only been employed in our supplementary measures.

In the following table all observations, whether made with or without the photometer wheel, or with a wide slit, as in the case of the supplementary observations in the most feebly luminous portions at the extremities in the spectrum, have been reduced to these standard conditions:

Photometer wheel absent;
Slit (s_1) $0\cdot 1^{mm}$ wide;
Slit (s_2) 1^{mm} wide;
Slider with logarithm table at 1 meter from slit s_2.

Each reading of the logarithms in the slider is taken when certain figures become discernible in the light in question, and is the mean of three independent observations, taken consecutively. In order to find the wave-length by means of the prism we must prepare a table or a graphic construction, deduced from an examination of the special prism employed, showing the wave-length corresponding to the position of mini-

3.



D=$\phi\lambda$.

mum deviation of each ray. Figure 3 is such a graphic construction derived from our own observations of the constants of the prism employed, and Table II gives the approximate values of the tangents to the curve by means of which we pass from the prismatic to the normal scale.

TABLE II.

Approximate deviations and reducing factors (tangents) corresponding to adopted wave-lengths for great Hilger prism.

Wave-lengths. μ	Adopted Tangents to curve.	Deviations.
·35	2·28	48°00′
·38	1·94	47 10
·40	1·73	46 42
·45	1·27	45 42
·50	·88	44 58
·55	·62	44 28
·60	·46	44 07
·65	·36	43 50
·70	·30	43 38
·75	·27	43 26
·768	·26	43 22

TABLE III.

Co-efficients of reflections from two surfaces of silver.

Wave-lengths	·35	·38	·40	·45	·50	·55	·60	·65	·70	·75
Percentage reflected from two surfaces	·37	·54	·63	·73	·79	·82	·845	·86	·875	·885
Reduction factor (reciprocal)	2·70	1·85	1·59	1·37	1·27	1·22	1·18	1·16	1·14	1·13

Table III is a table for the selective absorption of silver referred to such a lamina as is spread by the Martin process on the front surface of the glass in its ordinary application. It is prepared from unpublished observations made by the writer with the bolometer in the course of the year 1881, and for the method of its preparation the reader is referred to the foot note.* It will be seen from this table that while such a silver film exercises a considerable selective absorption in the ultra violet and even at the blue end, it exercises less as the wave-length increases, and in fact an extension of it would show a still enhanced power of reflection for infra red rays. It is with these infra-red rays that our measures in previous researches on radiant heat at this observatory have been hitherto mainly made. Accordingly our measures of the selective reflection in the ultra violet, to which we have given comparatively little study, have not been repeated with all the care which the subject deserves, and we recommend a more complete determination

* The selective absorption of silver has been deduced by bolometric measurements in the solar spectrum, with a Rutherfurd grating, by producing multiplied successive reflections of the light from silver before allowing it to enter the slit of the spectroscope and determining successively the variation in the intensity of different rays according to the number of reflections. The observations are reduced by a logarithmic formula.

of the selective absorption of silver there as an interesting field still open for experiment to those engaged in the study of that end of the spectrum.

By means of this graphic construction, which is amply accurate for the immediate purpose, and by the use of the formula already described (Memoirs of the National Academy, vol. ii, p. 161), we can also pass from the actually observed prismatic spectrum to the effect which would have been observed in a truly normal one; and it is by the use of these constructions, founded on these formulæ, that the final reductions here given have been obtained. It is here assumed that no sensible selective absorption is exerted by the prism or any other portion of the apparatus.

We now give a summary of the photometric observations. The state of sky for each series and the approximate air masses were:—

March 30th.—Sky "fair blue;" observer, S. P. L.; time, $11^h\ 40^m$ A. M. to $12^h\ 45^m$ P. M. (Greenwich 5th hour meridian time); air mass,* 1·22 atmospheres.

April 2d.—Sky "milky blue with cumuli;" observer, F. W. V.; time 12^h to 2^h P. M.; air mass, 1·19 atmospheres.

April 3d.—Sky "blue with cumuli," better than on 2d, sky better in E. M.'s series than in that of F. W. V., when a slight haze, barely perceptible, had formed.

1st series; observer, E. M.; time, $11^h\ 10^m$ A. M. to $12^h\ 30^m$ P. M.; air mass, 1·18 atmospheres.

2d series; observer, F. W. V.; time, $1^h\ 15^m$ to $2^h\ 30^m$ P. M.; air mass, 1·28 atmospheres.

April 4th.—"A good blue at first, after 12^h milky blue from slight smoke, but still a fairly good sky."

1st series; observer, F. W. V.; time, $10^h\ 25^m$ to $11^h\ 55^m$ A. M.; air mass, 1·23 atmospheres.

2d series; observer, E. M.; time, $12^a\ 30^m$ to $1^h\ 30^m$ P. M.; air mass, 1·20 atmospheres.

April 6th.—Sky "good blue, quite clear;" observer, F. W. V.; time, $10^h\ 45^m$ A. M. to $12^h\ 15^m$ P. M.; air mass, 1·18 atmospheres.

June 16th.—Sky "clear, good blue; after 1 P. M. cirrus streaks. Observer, B. E. L.; time, $11^h\ 15^m$ A. M. to $1^h\ 45^m$ P. M.; air mass, 1·05 atmospheres.

July 2d.—Sky "clear, excellent;" observer, B. E. L.

1st series; time, $11^h\ 25^m$ A. M. to $12^h\ 15^m$ P. M.; air mass, 1.03 atmospheres.

2d series; time, $12^h\ 15^m$ P. M. to $1^h\ 25^m$ P. M.; air mass, 1·02 atmospheres.

* By air mass is here meant that actually traversed by the solar rays, that with a vertical sun at sea level being unity.

We first give, in table IV, the values of the photometric measures in the prismatic spectrum, reduced to the standard conditions above cited.

TABLE IV.

Showing sensitiveness of the eye to light, as deduced from the power to decipher fine print.
Prismatic (uncorrected) values.

$\lambda=0^{\mu}{\cdot}35$		$0^{\mu}{\cdot}38$	$0^{\mu}{\cdot}40$	$0^{\mu}{\cdot}45$	$0^{\mu}{\cdot}50$	$0^{\mu}{\cdot}55$	$0^{\mu}{\cdot}60$	$0^{\mu}{\cdot}65$	$0^{\mu}{\cdot}70$	$0^{\mu}{\cdot}75$	$0^{\mu}{\cdot}768$
S. P. L.											
Mar. 30				0·29	3·01	19·31	19·15	3·88	0·28		
F. W. V.											
April 2			0·13	9·89	57·94	113·3	15·14	1·06	0·27		
April 3			0·30	9·88	154·2	167·9	26·91	1·99	0·43		
April 4			0·20	10·88	154·6	193·8	24·62	2·23	0·33		
April 6	0·0015*	0·017*	0·17*					2·32		0·005*	0·0012*
Mean	0·0015	0·017	0·20	10·25	122·25	158 33	22·22	1·90	0·34	0·005	0·0012
B. E. L.											
June 16			0·24	30·60	157·2	217·0	36·98	3·39	0·17	0·001*	
July 2	0·000*	0·003*	0·23	10·89	125·7	142·3	33·96	4·54	0·73	0·004*	
July 2			0·34	35·38	186·1	158·7	70·16	5·98	0·75		
Mean	0·000	0·000	0·27	25·62	156 3	172·7	47·03	4·64	0·55	0·002	
E. M.											
April 3			0·35	30·60	100·1	146·1	49·82	5·85	1·46		
April 4			0·19	8·34	46·39	75·27	42·05	3·04			
Mean			0·27	19·47	73·25	110·69	45·94	5 45	1·46		

* Blue (cobalt) glass over slit s_1.

In table V are the final values, corrected for loss of light by reflection from silver surfaces and reduced to the normal spectrum.

TABLE V.

Photometric values. Normal Spectrum.

$\lambda=0^{\mu}{\cdot}35$		$0^{\mu}{\cdot}38$	$0^{\mu}{\cdot}40$	$0^{\mu}{\cdot}45$	$0^{\mu}{\cdot}50$	$0^{\mu}{\cdot}55$	$0^{\mu}{\cdot}60$	$0^{\mu}{\cdot}65$	$0^{\mu}{\cdot}70$	$0^{\mu}{\cdot}75$	$0^{\mu}{\cdot}768$
S. P. L.											
Mar. 30				0·50	3·36	14·61	10 40	1·62	0 096		
F. W. V.											
April 2			0·36	17·21	64.76	85·69	8·22	0·44	0·092		
April 3			0·81	17·18	172·4	127·0	14·61	0·83	0·15		
April 4			0·56	19·11	172·8	146·7	13·37	0·93	0·11		
April 6	0·0092*	0·062*	0·47*					0 97		0·0015*	0·0003*
Mean	0·0092	0·062	0·55	17·83	136·65	119·8	12 07	0·79	0·117	0 0011	0·0003
B. E. L.											
June 16			0·65	53·23	175·7	164·2	20·07	1·42	0·058	·0003*	
July 2	0·000*	0·011*	0·63	18·95	140·5	107·6	18·44	1·90	0·25	·0012*	
July 2			0·94	61·56	208·0	120·0	38·09	2 50	0·26		
Mean	0·000	0·011	0·74	44·58	174·7	130·6	25·53	1·97	0·189	·0008	
E. M.											
April 3			0·95	53·23	111·9	119 5	27 05	2 44	0·50		
April 4			0·52	14·51	51·84	56 94	22·82	1·27			
Mean			0·74	33·87	81·87	83·72	24·94	1·86	0·50		

* Blue (cobalt) glass over slit (s_1).

In this table we have first, the wave-lengths corresponding to the observed angles of deviation, these values reaching from $0^{\mu}{\cdot}35$ in the ultra-violet to $0^{\mu}{\cdot}77$ near Fraunhofer's A on the extreme border of the visible red. It is to be observed, however, that the great mass of the observations which were taken without disturbing the slit reach from $0^{\mu}{\cdot}40$ in the deep violet to $0^{\mu}{\cdot}70$ in the deep red. The figures corresponding to $0^{\mu}{\cdot}35$, $0^{\mu}{\cdot}38$, $0^{\mu}{\cdot}75$, $0^{\mu}{\cdot}77$ are extremely difficult to obtain with precision and are given here as supplementary to the others. There are four observers:—

S. P. L., whose eye is somewhat long-sighted (making convenient the use of convex glasses of ½ meter focus) and not sensitive to very feeble light; eyes otherwise believed to be in normal condition.

F. W. V., near-sighted, using glasses whose negative focus is 14^{cm}. The eye appears to be much less sensitive to the red than to the violet. The retina of this eye is somewhat deficient in black pigment.

B. E. L., near-sighted, using glasses whose negative focus is 42^{cm}.

E. M., a boy of fifteen whose sight is perfect as far as known.

It will be remembered that throughout this table from $0^{\mu}{\cdot}40$ to $0^{\mu}{\cdot}70$ the light enters through a slit whose aperture is constant. If under these conditions the logarithm table can be just read when the slider is one meter from the second slit (s_2), the light would be represented by unity; if at two meters, by 4; if at three meters, by 9; and so on. As, however, we have already explained, the length of the red being limited to but little over three meters, for the higher values we are obliged to introduce the photometer wheel. For instance, the strongest light observed by F. W. V. was in the prismatic yellow-green corresponding to a wave-length of $0^{\mu}{\cdot}55$ where 193·8 was noted. Had the rod been really indefinitely prolongable, the slider would have needed to have been removed to the length of nearly 14 meters. To avoid this the photometer wheel was interposed, reducing the light to $\frac{1}{20}$ and the actual distance of the slider from the slit (s_2) was, as we may easily see, $\sqrt{\frac{193{\cdot}8}{20}}$ or 3·11 meters. The feeblest light which has been here measured with the standard slit is that by F. W. V. on April 2d at wave-length $0^{\mu}{\cdot}40$ which is put down at 0·13 corresponding to a distance of 36^{cm} from slit (s_2).

To make clear the way in which we pass from table IV to table V, let us take any particular observation, for instance that already cited of April 4th by F. W. V. at $0^{\mu}\cdot55$, of 193·8. Referring either to the graphic construction, or to table I, we find the value of the tangent (at $\lambda=0^{\mu}\cdot55$)=0·62 approximately, and $193\cdot8\times\cdot62=120\cdot16$. Our table shows the reduction factor for two surfaces of silver to be 1·22, whence the final reduced value becomes

$$1\cdot22\times120\cdot16=146\cdot6$$

And in this manner from tables II and III the remaining values in table V are derived from those in IV; but here let it be observed that these values in table V do not yet represent what we wish, since they do not correspond in any exact sense to one constant amount of energy. It is true that they might at first sight appear to do so, since one constant quantity of solar energy actually or virtually entered through the same constant width of the slit to produce them, and passed through one constant aperture at the second slit, and since finally the prismatic values are reduced to these in the normal spectrum; but, as the writer has shown not only by theoretical deductions from what is observed with the prism, but by very numerous measures in the normal spectrum from a grating by means of a bolometer, the solar energy in the normal spectrum itself is very unequally distributed. (See table I.)

Since thermal and luminous effects vary proportionately in the same ray, it is to be observed that the values in table I furnish for each wave-length a divisor which gives not only the heat but the *brightness* which would have been observed had the prism dispersed the energy which fell on it in such a way that the same amount of energy fell in one part of the spectrum as in another, and thus we finally obtain the values in table VI

TABLE VI.

Sensitiveness of the eye for a constant amount of energy of varying wave-length.

$\lambda=$	$0^{\mu}\cdot34$	$0^{\mu}\cdot38$	$0^{\mu}\cdot40$	$0^{\mu}\cdot45$	$0^{\mu}\cdot50$	$0^{\mu}\cdot55$	$0^{\mu}\cdot60$	$0^{\mu}\cdot65$	$0^{\mu}\cdot70$	$0^{\mu}\cdot75$	$0^{\mu}\cdot768$
S. P. L.				0·042	0·194	0·706	0·475	0·073	0·004		
F. W. V.	0·0051	0·0168	0·104	1·50	7·90	5·79	0·551	0·036	0·005	0·00007	0·00001
B. E. L.	0·000	0·0030	0·139	3·75	10·10	6·31	1·17	0·089	0·009	0·00004	
E. M.			0·140	2·85	4·73	4·04	1·14	0·084	0·023		
Mean*	*0·0026*	*0·0149*	*0·128*	*2·70*	*7·58*	*5·38*	*0·954*	*0·070*	*0·012*	*0·00006*	*0·00001*

* The observations of S. P. L. are here omitted from the mean.

It will be observed that no correction has been introduced for selective absorption in the substance of the prism itself, as this is absolutely negligible within the limited range of the spectrum we are discussing.

This table exhibits the relative effect upon very different eyes of a given amount of energy in the form of radiation of various wave-lengths.

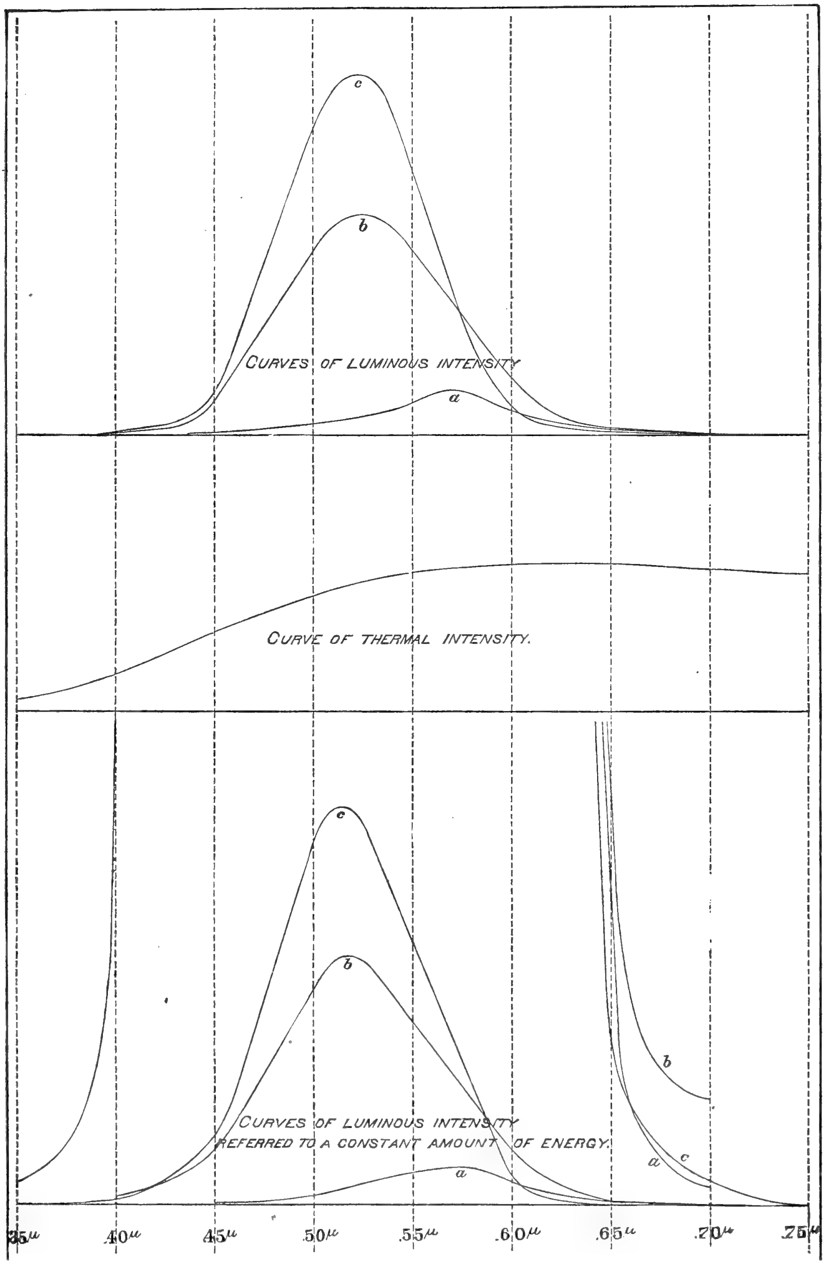
Quite notable differences exist between the different observers, not only as to the absolute sensitiveness of the eye, but also as to the relative efficiency for different colors. This seems to be, to some extent, a function of the age of the observer, if we may draw any conclusion from so few comparisons, the younger eyes being much more sensitive to the rays of shorter wave-length. Beyond this, any unusual efficiency for a particular part of the spectrum is perhaps apt to be balanced by a deficiency in another part, which, if strongly pronounced, would be termed color blindness. Prof. J. Clerk-Maxwell, employing pure spectrum colors, formed white by combining 26·3 per cent of red with 30·2 per cent of green and 43·5 per cent of blue (Phil. Trans. R. Soc., 1860, p. 79) and on another occasion with a slightly different apparatus (loc. cit. p. 74) the same observer made white by mingling 21·9 per cent of red with 33·3 per cent of green and 44·8 per cent of blue. The Allegheny observers, F. W. V., B. E. L., and E. M., with whom this experiment was repeated, required from one fourth to one-tenth less red and one-sixth to one-eighth more blue than Maxwell, forming white by mingling 20 per cent of red with 30 per cent of green and 50 per cent of blue. Since, in order to make white, more of that color is required for which the eye is most sensitive, we may perhaps infer that Prof. Maxwell was somewhat less sensitive to blue than these observers, although it should be remembered that the relative intensity of the blue and red in the solar spectrum is liable to undergo considerable fluctuations, so that where direct comparison of individual eyes is impossible, some uncertainty must remain.

We have selected for comparison with our results the following by Capt. Abney (using a different photometric method), which we have here reduced to the normal scale. (See "Transmission of Sunlight through the Earth's atmosphere," by Capt. W. de W. Abney, R.E., F.R.S.; Phil. Trans. R. Soc., vol. 178, (1887), A., pp. 274–276). From the mean of the observations of July 1st, July 5th and July 21st, 1886, made with an average air-mass of 1·33 atmospheres, we obtain these photometric values for the normal spectrum:

$\lambda=$	$0^{\mu}\cdot40$	$0^{\mu}\cdot45$	$0^{\mu}\cdot50$	$0^{\mu}\cdot55$	$0^{\mu}\cdot60$	$0^{\mu}\cdot65$	$0^{\mu}\cdot70$
Light=	0·8	2·8	25·0	82·0	66·5	12·3	0·5

The general form of this curve agrees with that of S. P. L. (curve *a*, fig. 4), showing a maximum sensitiveness near $\lambda = 0^{\mu}\cdot 57$.

4.



The light curves of F. W. V. (curve *c*, fig. 4), and of E. M., (curve *b*, fig. 4), have their maxima respectively near $\lambda=0^{\mu}\cdot52$ and $\lambda=0^{\mu}\cdot53$.

Everything which has preceded has had reference to the *relative* luminous effects produced by *any* (moderate) constant quantity of energy. It may, however, be interesting to make the novel calculation as to the actual amount of energy either in horse power or any other unit required to make us *see*, and we can obtain an approximate estimate of this amount of energy as follows:

Actinometric measurements, made during the progress of the photometric observations, showed a solar radiation of 1·5 calories per square centimeter per minute. Of this amount of heat the slit (s_1), being $3^{cm}\cdot4$ high by $0^{cm}\cdot01$ wide, received the fraction 0·034. The visible spectrum from A to H, included, according to the bolometer measures, about 21 per cent of the total energy, the absorption of the lower infra-red by the great thickness of glass in the prism being large. We estimate that nearly 20 per cent had been lost by reflection before the bolometer was reached. The spectrum formed had a length of 86^{mm} from A to H. The *average* energy which passed through the millimeter aperture of slit s_2 was therefore (within these limits and expressed as heat),

$$1^{cal}\cdot5\times0\cdot034\times0\cdot21\times0\cdot8\times\frac{1}{86},$$

or approximately $\frac{1}{10000}$ calorie, let us say 4,000 ergs per minute.

At 1 meter from slit s_2, this energy is further spread out over an illuminated area of 28 sq. cm., of which the square centimeter of fine print, being placed at an angle of 45° with the path of the ray, occupies only about $\frac{1}{40}$. If a length of 1^{mm} of the standard spectrum receives an average energy of $\frac{1}{10000}$ calorie per minute, the actual working part of the screen, consisting of the little square of fine print, will receive at a distance of 1 meter $\frac{1}{4000000}$ calorie per minute. But this by no means gives the amount of energy requisite to produce vision, since the eye is able to receive a distinct visual impression in less than one-half second of time. We may say, therefore, that a luminous energy of $\frac{1}{500000000}$ calorie is sufficient to give a distinct view of the small square of figures in the brightest part of the spectrum, even after the immense loss of light by absorption and diffusion in the paper, which may amount to $\frac{19}{20}$ of the whole.

Even less light is needed to give the bare impression of luminosity. The sensitiveness of the human eye is indeed so extraordinary, that the chief difficulty in measuring its power is to find means for sufficiently reducing the intensity of sunlight,

which are at the same time capable of even approximate numerical estimation. Out of numerous plans tried, the following has given the most reliable result.

In front of the first slit, in the path of the rays from the siderostat, was placed a plate of glass very lightly smoked whose transmission for different kinds of light was first photometrically measured and found to be

For violet light		$(\lambda=0^{\mu}\cdot40)$	transmission	0·000210
" green	"	$(\lambda=0^{\mu}\cdot55)$	"	0·000655
" red	"	$(\lambda=0^{\mu}\cdot65)$	"	0·002350

The photometer wheel was next interposed, its aperture being sometimes reduced until only 2 per cent of the light received passed through it.

The slit was at first kept as near the standard width of $0\cdot1^{mm}$ as possible; but it was afterwards deemed best to secure the final adjustment for the *minimum visibile* at the slit, as it was evident on trial that the inaccuracy due to the varying loss by diffraction was small, compared with the inevitable uncertainty of the observer himself.

Finally, the larger part of the necessary reduction was secured by reducing the aperture of the collimating lens by means of a metal plate pierced by a minute aperture whose area, $0\cdot00015^{sq\ cm}$, was 0·000003 of the fully illuminated area of the lens.

The aperture of the human eye, according to du Bois-Reymond's photograph (see Nature, May 3, 1888, p. 15), is about $0\cdot7^{sq\ cm}$, when fully expanded, or the same as that of the foreshortened disk of figures previously employed. The size of the light spot at the standard distance beyond slit s_2, when the minute aperture is placed over the collimating lens, is reduced so that about two-thirds of the light enters the eye placed 1 meter behind the 1^{mm} slit on which the spectrum is formed.

The following reductions of sunlight were needed in order to give a light which approximated to the *minimum visibile*, defining this to be, not the smallest light whose existence it is possible to suspect, or even to be reasonably certain of, but a light which is observed to vanish and reappear when silently occulted and restored by an assistant without the observer's knowledge.

Referred to the standard spectrum employed in the previous photometric work, the observer F. W. V. found:

Fraction of standard* violet light $(\lambda=0^{\mu}\cdot40)$ required for certain vision $=0\cdot00021\times100\times0\cdot000003=0\cdot000000{,}063$.

* By "standard" is here meant the light in 1^{mm} of the standard spectrum, whose length from A to H was 86^{mm}.

Fraction of standard green light ($\lambda=0^{\mu}\cdot55$) required for certain vision $=0\cdot000655\times0\cdot033\times0\cdot000003=0\cdot000000{,}0000655$.

Fraction of standard scarlet light ($\lambda=0^{\mu}\cdot65$) required for certain vision $=0\cdot00235\times2\cdot\times0\cdot000003=0\cdot000000{,}0141$.

Fraction of standard crimson light ($\lambda=0^{\mu}\cdot75$) required for certain vision$=10\cdot\times0\cdot000003=0\cdot00003$.

The measures were made on July 3d and 11th, the sky being a fairly good milky blue and the sun within one hour of the meridian.

Assuming that the energy per millimeter of the standard spectrum was 0·000001 calorie per half second for the wave-lengths $0^{\mu}\cdot55$ and $0^{\mu}\cdot75$, we have from table I:

For $\lambda=0^{\mu}\cdot40$, energy$=\ 5\cdot3\div(20\cdot7\times1{,}000000)$ calorie.
" $\lambda=0^{\mu}\cdot65$, " $=22\cdot2\div(20\cdot7\times1{,}000000)$ "

by means of which, we reduce each of the above values to absolute measure, obtaining for the maximum value of the

Minimum Visibile.

		Reciprocal of		Reciprocal of
Violet....	$0^{\mu}\cdot40$	63,000000,000000 calories	=	1,500000 ergs.
Green	$0^{\mu}\cdot55$	15000,000000,000000 "	=	360,000000 "
Scarlet ...	$0^{\mu}\cdot65$	66,000000,000000 "	=	1,600000 "
Crimson ..	$0^{\mu}\cdot75$	33000,000000 "	=	780 "

Stating these values in terms of horse power we have

Minimum Visibile.

		h. p.
Violet............	$0^{\mu}\cdot40$	0·000000,000000,00018000
Green	$0^{\mu}\cdot55$	0·000000,000000,00000075
Scarlet	$0^{\mu}\cdot65$	0·000000,000000,00017000
Crimson (near A)..	$0^{\mu}\cdot75$	0·000000,000000,34000000

The measurement of the *minimum visibile* is subject to variations of a much wider range than those of the photometric method and may perhaps be in error by 100 per cent.*

* The relative sensitiveness of the eye of the observer in question (F. W. V.) for the extreme red or violet, as compared with its power of detecting green light, appears to be somewhat less when determined by the method of *minimum visibile* than by the reading of fine print.

By the former we have

The probable error of a series of ten readings of fine print, under the actual conditions of observation with a (feeble) standard luminosity, is determined for two of the observers as follows:

	Violet Light $\lambda = 0^{\mu}{\cdot}40$	Orange-yellow light $\lambda = 0^{\mu}{\cdot}60$	Scarlet light $\lambda = 0^{\mu}{\cdot}65$
	Probable Error of one observation.		
	%	%	%
F. W. V.	5·53	1·76	3·14
E. M.	7·69	2·51	2·86
	Probable Error of mean.		
F. W. V.	1·75	0·56	0·99
E. M.	2·44	0·80	0·90

The measurements with violet light were made June 19, 1888, "sky hazy blue, thin but uniform cirrus haze." Those at wave-lengths $0^{\mu}{\cdot}60$ and $0^{\mu}{\cdot}65$ were obtained on June 20, 1888, "sky hazy blue with cumuli, haze not as dense as on the 19th but possibly less uniform."

For a large part of the spectrum the probable error of a single reading does not exceed 4 per cent but the error may considerably exceed this for the violet rays, *the eye requiring a much longer time to regain its sensitiveness for light of this color than for any other*, so that for measures in this region an hour's stay in the darkened room is none too much to develop the full power of an eye which has recently been exposed to the full sunshine.

Time required for Vision.

In connection with the photometric measures the time required for the perception of very faint colored lights was

Sensitiveness	violet ($^{\mu}{\cdot}40$) : green ($^{\mu}{\cdot}55$)=1 :	240
"	scarlet ($^{\mu}{\cdot}65$) : green ($^{\mu}{\cdot}55$)=1 :	230
"	crimson ($^{\mu}{\cdot}75$) : green ($^{\mu}{\cdot}55$)=1 :	450,000

Photometry by the reading of fine print gave for the same observer

Violet,	sensitiveness of eye		=0·104,000
Green,	"	"	=5·790,000
Scarlet,	"	"	=0·036,000
Crimson,	"	"	=0·000,070

unity being the sensitiveness for yellow light; and the relative effect by this method is

Violet	($^{\mu}{\cdot}40$) : green ($^{\mu}{\cdot}55$)=1 :	56
Scarlet	($^{\mu}{\cdot}65$) : green ($^{\mu}{\cdot}55$)=1 :	160
Crimson	($^{\mu}{\cdot}75$) : green ($^{\mu}{\cdot}55$)=1 :	83,000

investigated. The method was an electrical one. There was automatic registration on a chronograph of the instant of exhibition, and determination of the instant of response as the observer pressed a key. The interval of course includes quite a train of distinct operations. According to Mendenhall (this Journal, III, vol. ii, p. 156), that portion of the action of brain nerve, and muscle which produces the mechanical effect, and which may be called automatic, takes place in certainly but little over one-tenth of a second. But the sensations which demand a conscious concentration of the attention, and especially those which require for their registration a decision of the judgment, occupy an interval several times as great. The perception of a light just at the verge of visibility probably involves an exercise of judgment,—an answer to the question, "Do I see the light or do I not?"—although the question may not be consciously propounded, and accordingly this kind of perception may be included in that class of combined sensation and mental operation which involves a choice. Professor Mendenhall found for the time required to decide between red and white $0^{sec.}\cdot443$ and to decide between a circle and a triangle $0^{sec.}\cdot494$. We have found for the average of over 1000 observations of the disappearance or reappearance of a very faint light (perhaps 20 times as bright as the faintest perceptible), $0^{sec.}\cdot507$, but corresponding measures with a moderately bright spectrum, the light being about 10,000 times as intense as that called "very faint," gave $0^{sec.}\cdot242$, a number which is intermediate between the times found by Professor Mendenhall for the appearance of a white card ($0^{sec.}\cdot292$) and that of an electric spark ($0^{sec.}\cdot203$). We may therefore conclude that distinct vision for a very faint light demands about one half second of time, while the perception of light of ordinary brightness requires only about half that interval. It is possible that differences in the rapidity of the perception for lights of different colors might be detected on more exhaustive study, but none have been noted in these experiments other than those which were attributable to the variation of intensity.

It will be seen that quantitative measures of the effect upon the eye of different rays whose luminosity varied in the proportion of 200 000 : 1, were actually obtained and that it would have been possible to considerably exceed these limits, especially when it is considered that the photometric measures were confined to lights of feeble intensity. Since it is possible to look directly at the sun for as short a time as one-half second, it is certain that the eye, by the combined adaptability of the iris and retina, can perceive lights whose intensities vary in the ratio of 1 to 1 000 000000 000000.* $(10)^{15}$

* It may be interesting to check this result by an entirely different method. The light of the sun is, according to Pickering, equal to that of a star of $-25\cdot5$

It will be understood that the writer does not profess any competence in physiological optics, and that the preceding observations and the conclusions reached from them are both to be understood from the purely physical point of view. This being premised, we will summarize the paper in the following conclusions.

The time required for the distinct perception of an excessively faint light is about one-half second. A relatively very long time is, however, needed for the recovery of sensitiveness after exposure to a bright light, and the time demanded for this restoration of complete visual power appears to be greatest when the light to be perceived is of a violet color.

The visual effect produced by any given, constant amount of energy varies enormously according to the color of the light in question. It varies considerably between eyes which may ordinarily be called normal ones, but an average gives the following proportionate result for seven points in the normal spectrum, whose wave-lengths correspond approximately with those of the ordinary color divisions, where unity is the amount of energy (about $\frac{1}{1000}$ erg) required to make us see light in the crimson of the spectrum near A, and where the six preceding wave-lengths given correspond approximately to the six colors violet, blue, green, yellow, orange, red.

Color.	Violet.	Blue.	Green.	Yellow.	Orange.	Red.	Crims.
Wave-length,	$^{\mu}$·40	$^{\mu}$·47	$^{\mu}$·53	$^{\mu}$·58	$^{\mu}$·60	$^{\mu}$·65	$^{\mu}$·75
Luminosity, (Visual effect.)	1,600	62,000	100,000	28,000	14,000	1200	1

Since we can recognize color still deeper than this crimson, it appears that the same amount of energy may produce *at least* 100,000 times the visual effect in one color of the spectrum that it does in another, and that the *vis viva* of the waves whose length is 0^{μ}·75, arrested by the ordinary retina, represents work done in giving rise to the sensation of crimson light of 0·0000000000003 horse power, or about 0·001 of an erg, while the sensation of green can be produced by 0·000000,01 of an erg.

stellar magnitude, or 4400,000000 times that of Sirius (Mag. —1·4) which again is about 910 times that of a sixth magnitude star, ordinarily considered the faintest visible to the naked eye. Here the light of the sun is to that of the *minimum visibile* as 1 to 4,000000,000000 (4×10^{12}), but the difference seems accounted for by the fact that the ratio by this latter method is found for an eye exposed in starlight by the former for an eye in *absolute* darkness.

ART. XL.—*Mineralogical Notes;** by W. EARL HIDDEN.

Xenotime, from New York City.—In 1872 I discovered, in the vicinity of 155th street and 11th avenue, a single crystal of a mineral which I then determined to be xenotime. It occurred in a coarse pegmatite vein traversing gneiss and associated with much muscovite, tourmaline, orthoclase, quartz and apatite. The determination was based upon the form and physical characters which agreed with those of xenotime. This crystal was $\frac{3}{16}$ inch in diameter. It showed the planes 1 (111) and *I* (110) and in habit resembled figure 438 of Dana's System of Mineralogy. The planes were too uneven to allow of exact measurement.

In February of this year my attention was called, by Mr. William Niven, of New York, to a series of specimens he had lately collected in the same neighborhood. They included besides black tourmaline, dark green apatite, muscovite and orthoclase, two small brown crystals on separate specimens resembling zircon in form. An indication of prismatic cleavage and the inferior hardness (about 5) led me to believe them to be xenotime; this determination was confirmed by a chemical test of one of the crystals which yielded a large amount of P_2O_5. These new crystals have long prisms and very smooth planes, thus differing from the first one found in 1872. The color is dark hair-brown. It is similar in form to a crystal from Schüttenhofen† figured by R. Sharizer, excepting that it is much longer vertically. It is similar also to the xenotimes from Alexander County already described in this Journal‡ and to crystals from Hitterö, Norway lately described by G. Flink.§ Careful measurements were made by Mr. H. S. Washington, with a Fuess horizontal goniometer, of the angles of one of these New York Island xenotimes. He states that, "the images were very good and the angles are quite reliable and useful for comparison. They agree well with vom Rath's values."‖ The following were the best angles (supplement) obtained.

$$s \wedge s\ (111 \wedge 1\bar{1}1) = 55°\ 32'\ 30''$$
$$s \wedge r\ (111 \wedge 311) = 29°\ 50'\ 30''$$
$$\text{giving } \dot{c} : a = 0{\cdot}619431 : 1$$

Only three planes were observed, i. e., *s* (111), *m* (110) and *r* (311).

* Continued from vol. xxxiii, p. 501.

† "Zeitschrift für Krystallographie, etc.," xiii, 1, 1887, figure 1.

‡ This Jour., III, xxxii, p. 206, Sept., 1886.

§ Bihang till K. Svensk. Vet. Akad. Hand., xii, part 2, No. 2, p. 41 (1886).

‖ Jahrb. Min., 1879, p. 536.

Later work at this locality, by Mr. Nivens, has resulted in the finding of crystals of zircon (G. = 4·73), monazite (G. = 5·51), chrysoberyl, iolite, pinite, and two others, which I have not as yet identified, all new to the locality.

Xenotime, from Alexander Co., North Carolina.—In some concentrations of vein material from the locality formerly known as Milholland's Mill,* I have also found several brilliant brown transparent crystals of xenotime. An ounce of this sand yielded more than a dozen perfect crystals. They were minute, none of them exceeding 2^{mm} in length and from $\frac{1}{6}$ to $\frac{1}{2}^{mm}$ in thickness. The hardness was less than 5; the quantity was too minute to allow of a specific gravity determination. With these hair-brown xenotimes and topaz-yellow monazite also occur very brilliant ruby-red crystals of rutile and small muscovite crystals. The measurements of the angles were attended with considerable difficulty but the following satisfactory results were finally obtained:

$$s' \wedge s''' \ (111 \wedge \bar{1}\bar{1}1) = 96\tfrac{1}{2}^\circ \text{ approx.}$$
$$m' \wedge s' \ (110 \wedge 111) = 131\tfrac{1}{2}^\circ \text{ approx.}$$

As to the new plane *f* (2-*i*, 201), it was observed equally developed, as shown in figure 1, on all the crystals found. Its symbol is determined without measurement, by the fact that its terminal edge is truncated by the pyramid 1. It is to be hoped that the mining now going on in this region may bring to light macroscopic examples of this very interesting type of xenotime.

At a new locality, about $3\frac{1}{2}$ miles nearly due east, I found, in August, a few small crystals of xenotime of a dark brown color that had *polished* planes. They were found associated with monazite, rutile, muscovite and quartz crystals.

Xenotime-zircon, from a new locality.—On the Davis land, on the east side of the road that leads from Zirconia Station to Greenville, via. "Poinsetts Spring;" and distant about four miles from Green River Post Office, Henderson County, North Carolina, there is an outcropping of decomposing granite that has lately yielded a small quantity of very interesting minerals; only one of which I shall describe at this time.

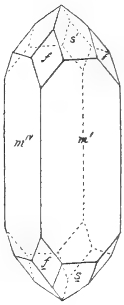
A cubic yard of the partly kaolinized material yielded on washing nearly an ounce of a mixture of zircon, monazite, xenotime, a member (as yet unidentified) of the samarskite group, and considerable magnetite in octahedral crystals. Figure 2 shows the symmetrical development of the largest xenotime found, and its association, in parallel position, with a crystal of zircon. The specimen is nearly one centimeter thick. The zircon crystal forming the center is bright dark-brown and the xeno-

* Now Warren's. On the monazite from this locality see this Journal, xxii, 21, 1881, and xxiv, 247, 1882.

time has a pale yellowish gray color. The planes on both are smooth but unsuited for correct measurement.

These symmetrically compounded crystals of zircon and xenotime were first noticed by Zschau on specimens from Hitterö, Norway. In 1879 I found similar crystals at the

1



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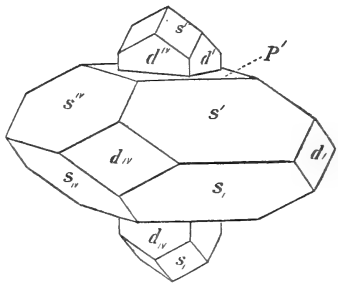


Mills' gold mine* (placer washing), in Burke County, N. C. The xenotime here figured is especially interesting from the presence of the rare planes *P* (001) and *d* (100); both of which have been observed by Flink on Norway crystals.† The basal plane I have myself observed on a large crystal from the bastnæsite locality‡ in Colorado.

Of the seventeen distinct crystals of xenotime found at this locality, seven (the largest) had zircons enclosed in parallel position and one showed the plane 3-3 (311). Of the associated minerals, there were noticed two varieties of zircon: the ordinary gray crystals and the soft dark-brown cyrtolite variety with curved faces. The latter seems to be the only kind as yet found compounded with xenotime.

Xenotime-zircon, from Mitchell County, N. C.—On the cyrtolite from the Deake mica mine I have lately observed a single instance of xenotime occurring (in patches only) in parallel position; resembling greatly the Henderson County crystals above described. The associations were gummite and uraninite.

Xenotime, from McDowell Co., N. C.—I have lately received from Mr. T. S. Ash, several xenotime crystals that were found near Dysartsville,§ McDowell County, N. C.; one of these is 14^{mm} in diameter. One clear brown crystal (3×5^{mm}) exhibits a type of form which I have not seen credited to the species. The crystal is made up of only the one form *s* (1, 111), but the faces, while smooth and polished, are

* This Journal, vol. xxi, p 244. † This Journal, xx, p. 273.
‡ This Journal, vol. xxix, p. 248.
§ Three miles west from the Mills mine above cited.

curved and twisted in a manner comparable only to those strangely contorted smoky quartz crystals from Mount St. Gothard, Switzerland, and to some crystals of pearl-spar (dolomite). The crystal described is so bent that an edge *s'/s* (111/11$\bar{1}$), which should be horizontal, stands nearly at an angle of 45° from its proper position. The crystal weighs one-sixth of a gram and has a density of only 4·27. The prismatic cleavage is well marked by internal reflections. The hardness seems to be slightly above five.

Newark, N. J., September 7th, 1888.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Relation of Solubility to Fusibility.*—Carnelley and Thomson have devised a simple and efficient apparatus for determining the solubility of substances in various solvents and have applied it to the estimation of the solubility of the isomers meta-nitraniline and para-nitraniline in thirteen different solvents. With the aid of these results, together with others already on record, these authors have discussed the close relation which exists between the solubility of isomeric carbon compounds and their fusibility, already pointed out by one of them several years ago. Starting from the observation of Pictet that the lower the melting point of a solid, the longer are the oscillations of its molecules, so that the product of the melting point, measured from the absolute zero, by the length of oscillation is constant, the authors reason that of two isomers, the one with lower melting point will, at any temperature below this point, have its molecules moving with oscillations of greater amplitude than the one with the higher melting point; and consequently, the molecular weights being equal, the force of restitution will be less in the case of the more fusible compound, and its molecules, being in a less stable condition, will be the more readily separated from their fellows. Now inasmuch as, in order that a solid may dissolve in any liquid, its molecules must undergo a sort of unloosening process, the conclusion is legitimate that of two isomeric bodies, that one should dissolve the more readily in which the attraction toward the mean position is least, i. e., the more fusible one. The authors conclude: 1st, that for any series of isomeric organic compounds, the order of solubility is the same as the order of fusibility, the more fusible body being the more soluble one. 2d, in any series of isomeric acids, not only is the order of solubility of the acids themselves the same as the order of fusibility, but the same order of solubility extends to all the salts of these several acids; so that the salts of the more soluble and more fusible acids are also more easily soluble than

the corresponding salts of the less fusible and less soluble acids. In order to test the first law, 1778 cases of isomeric compounds were examined as to fusibility and solubility; and of these 1755 were found to agree with the rule. With regard to the second law, 138 out of 143 cases were found to obey it. Of the 28 exceptions to both laws, 16 there is reason to believe are only apparent; leaving only 12 at the most, not at present explicable. On investigating the influence of the nature of the solvent, the authors find: 1st, that for any series of isomeric compounds the order of solubility is the same whatever be the nature of the solvent. And 2d, that the ratio of the solubilities of the two isomerides in any given solvent is very nearly constant and is therefore independent of the nature of the solvent. The former rule was found to hold in every one of 666 cases examined; and the latter in the case of the two nitranilines with the 13 solvents as above described. The authors are disposed to regard the relation of fusibility to solubility as but a part of a more general law, i. e., that the properties of the corresponding derivatives of two or more isomeric compounds are related to one another in the same way as those of the primitive isomers themselves. This relation however need not be restricted to isomeric bodies; and the paper shows its existence in the allotropic forms of phosphorus, selenium and sulphur, in paraffin, and in mixtures of potassium and sodium nitrates.—*J. Chem. Soc.*, liii, 782, Sept., 1888. G. F. B.

2. *Raoult's method for determining Molecular Weights.*—The method of RAOULT for determining molecular weights consists in measuring the amount by which the solidifying point of a solvent is lowered by a known weight of a dissolved substance; the apparatus required being only a vessel to contain the solvent and a thermometer reading to tenths. V. Meyer, having used it successfully, somewhat modified, to prove the identity in molecular weight of two isomers he was investigating, his associate AUWERS was led to a study of the conditions most essential to its successful employment in the laboratory. The formula used is $M=T\div A$, in which M is the molecular weight, T the molecular depression and A the depression caused by one gram of substance in 100 grams of solution. The value of T is first to be determined, which is accomplished by taking members of the series of compounds under consideration (for which this value is constant) of known molecular weight. The selection of a solvent is a matter of prime importance, since it is necessary that no chemical action should take place between it and the substance to be tested. Water is objectionable not only because of its tendency to form hydrates, but also because of its limited solvent power for most organic bodies, and because a considerable amount of material is required. Benzene is better, but its use is also limited. The best solvent is glacial acetic acid, which can be used with a great range of substances. The errors are small and it is quite sufficient to secure a depression of about 0·3°. It may be used at

ordinary temperatures, provided a closed space be employed such as the author describes. Experiments with naphthalene and picric acid, acetanilide and benzil, and the isomeric diacetyl-compounds of β-diphenylglyoxime are described in the paper.—*Ber. Berl. Chem. Ges.*, xxi, 701, 784, 860, 1068, March, April, 1888. *J. Chem. Soc.*, liv, 408, 597, May, June, 1888. G. F. B.

3. *On the Vapor-density of Hydrofluoric acid.*—THORPE and HAMBLY have published a preliminary note on the vapor-density of hydrogen fluoride. The object of their experiments was to ascertain whether this gas possesses a constitution agreeing with the formula H_2F_2, assigned to it by Mallet from its density at 30·5°, through any considerable range of temperature. By means of a large platinum apparatus provided with stopcocks of the same metal the vapor density of hydrogen fluoride was determined at temperatures varying from 26·4° to 88·3°. The material was prepared pure as required for each experiment, from acid potassium fluoride, and was then redistilled through the platinum apparatus placed in a bath of glycerin. Fourteen experiments at short intervals between the limits of temperature given, afforded values corresponding to molecular weights ranging from 51·19 at 26·4° to 20·58 at 88·3°. It appears therefore that there is in this case a gradual and progressive breaking down of a complex molecular grouping, analogous to that observed in the case of acetic acid.—*J. Chem. Soc.*, liii, 765, August, 1888. G. F. B.

4. *On the Spectrum of Oxygen.*—JANSSEN, in his observations on the Pic du Midi, has shown that the indistinct bands in the spectrum of oxygen become visible in the solar spectrum when the layer of the atmosphere through which the sun's light passes is sufficiently large. He has confirmed the existence of these bands and has proved, by a series of observations ranging from atmospheric pressure to a pressure of 100 atmospheres, with tubes varying from 0·42 to 60 meters in length, the law that the intensity of these bands is proportionate to the product of the diameter of the layer of oxygen into the square of the density of the gas. Janssen has calculated that the bands should be just visible with a layer of liquid oxygen four or five millimeters in thickness; and the result of the calculation has been verified by Olzewski who has experimentally observed them in a layer seven millimeters thick.—*C. R.*, cvi, 1118, April, 1888. G. F. B.

5. *On the Valence of Oxygen.*—In order to avoid the high valence of the haloids, on the one hand, in their oxygen acids, and on the other, the long and fragile atomic chain, HEYES has suggested that oxygen should be considered as quadrivalent, the haloids themselves being trivalent. Thus written potassium hypochlorite becomes $K-Cl=O=O=Cl-K$; and the chlorate and perchlorate are to be viewed as formed of the group $K-Cl=$ joined to groups of oxygen atoms $(O_3)''$ or $(O_4)''$, in such a way perhaps as to form a closed chain. Moreover the author believes

that by supposing the haloid elements to be trivalent, the molecular compounds of their salts can be better explained than is possible if the atoms are grouped about a central atom of high valence. The author thinks that the properties of the peroxides BaO_2 and MnO_2, which are quite distinct from those of SiO_2 and SnO_2, point to a formula $R''=O=O$, and thus sustain the quadrivalence theory. The same is true of the oxides of silver, mercury and copper. As sodium dioxide is not decomposed by heat, he supposes it to have the structure $Na-O-O-Na$; although in K_2O_4 he assumes an oxygen nucleus $(O_4)''$ analogous to that in $KClO_4$ and Cl_2O_4. Moreover, this view that oxygen may act as a tetrad, at least occasionally, is supported by the interaction of water with various organic substances such as aldehyde, acetal and acetic acid, by Ramsay and Young's gaseous acetic acid molecule $C_4H_8O_4$ and by the substance $(CH_3)_2O{\cdot}HCl$, described by Friedel. The same is true of the double metallic oxides, basic salts, and water of crystallization $(-OH_2.OH_2.OH_2-)$. The author proposes the term *validity*, in cases where the same atom has two valences, to indicate the less powerful attraction; so that chlorine would be univalent and trivalid, carbon is quadrivalent except in CO and CNO where it is bivalid. As J. J. Thomsen has shown, according to the vortex theory a dyad may unite not only with two but also with four monad atoms; so that water may consist of three primaries H_2-O-O. With this conclusion the author's formula $H_2=O=O$ evidently agrees. It agrees also with Brodie's $H_2\overset{+}{O}\overset{-}{O}$.—*Phil. Mag.*, V, xxv, 221.

G. F. B.

6. *On the Carbon Atom and Valence.*—V. MEYER and RIECKE have pointed out that the theoretical conclusions of Van't Hoff and Wislicenus, supported and extended as they have been by the experiments of Meyer and others on the isomeric benzil-dioximes, require a modification in the generally accepted theory of the carbon atom and necessitate the addition to it of the two following properties: (1) The four valences of the carbon atom can be diverted from the regular tetrahedric direction in which they are supposed to exist in marsh gas and compounds of the constitution Ca_4; and (2) There are two ways in which two singly bound carbon-atoms can be united, one which allows free rotation in various directions, and one which does not. On various chemical and physical grounds, the authors offer the following hypothesis on the constitution of the carbon-atom: The carbon-atom is surrounded by an ætherial shell which in the case of an isolated atom, has a spherical form; the atom itself is the carrier of the specific affinities, the surface of the shell is the seat of the valences; each affinity is determined by the existence of two opposite electrical poles which are situated at the end-points of a straight line small in comparison with the diameter of the æthereal shell. Such a system of two electric poles is called a double or di-pole. The four valences of a carbon atom would be represented by four such di-poles, the middle

points of which are situated on the surface of the æthereal shell, but freely moveable within it. The di-poles themselves can rotate freely round their middle point. The carbon atom has a greater attraction for positive than for negative electricity and the positive pole of a valence is slightly stronger than the negative pole. The following facts, it will be observed, become explicable upon the above hypothesis: (1) why the four valences take up the position of a regular tetrahedron; (2) why they can be diverted from this position; (3) why the valences of one and the same carbon-atom cannot combine together, while the valences of different carbon-atoms can do so; (4) why there are two kinds of single binding (*a*) a stable one and (*b*) one allowing free rotation; and (5) why free rotation ceases in cases of double or triple-binding.—*Ber. Berl. Chem. Ges.*, xxi, 946, March, 1888; *J. Chem. Soc.*, liv, 549, June, 1888. G. F. B.

7. *The Chemical Analysis of Iron;* by ANDREW ALEXANDER BLAIR. 282 pp. 8vo, Philadelphia, 1888. (J. B. Lippincott Company).—In this volume the author has given a full account of the methods employed in the analysis of iron and steel, iron ores, slags, limestone, clay, sand, the fuels, furnace gases. It is exhaustive in method, describing the apparatus and the methods of making reagents as well as the details of the quantitative processes by which the various constituents are determined. The execution of the work as regards printing, cuts, etc., is unusually good, and fully up to the excellence of the subject matter.

8. *Interference of Electro-magnetic Waves.*—Professor FITZGERALD, Vice President of the Mathematical and Physical sections of the British Association at the late meeting at Bath, England, thus speaks of Hertz's work. "There are some difficulties surrounding the complete interpretation of some of Hertz's experiments. The conditions are complicated, but I confidently expect that they will lead to a decision on most of the outstanding questions on the theory of electro-magnetic action. There is no doubt that he has observed the interference of electro-magnetic waves quite analogous to those of light, and that he has proved that electro-magnetic actions are propagated in air with the velocity of light. By a beautiful device Hertz has produced rapidly alternating currents of such frequency that their wave-length is only two meters. These waves are propagated three hundred thousand kilometers in a second. To detect them he made use of the principle of resonance, and constructed a circuit whose period of vibration for electric currents was the same as that of his generating vibrator, and he was able to see sparks, due to the induced vibration, leaping across a small air space in this resonant circuit. He has been able to observe the interference between waves incident on a wall and the reflected waves. His generating vibrator was placed several wave-lengths from a wall and the receiving resonant circuit was placed between the generator and the wall. In the air space he was able to observe that at some points there were hardly any induced sparks, but at other and at greater dis-

tances from his generator they reappeared, to disappear again in regular succession at equal intervals between his generator and the wall. It is exactly the same phenomenon as what is known as Lloyd's bands in optics, which are due to the interference between a direct and a reflected wave. It follows that just as Young's and Fresnel's researches on the interference of light prove the undulatory theory of optics, so Hertz's experiment proves the ethereal theory of electro-magnetism."—*Nature*, Sept. 6, 1888, p. 446.

J. T.

9. *Ultra violet Spectra of Metalloids.*—M. DESLANDRES gives a full history of the work of previous observers and discusses the division of the spectra into groups, particularly of the ultra violet spectrum of ozone, which he believes to be composed of that of ozone and oxygen. He has also verified the law that the band spectra show a repetition of similar bands or series of similar lines, and present an analogy to lines of metals which show a similar repetition. He indicates a simple relation between the spectrum of the vapor of water and that of oxygen, that is to say, between the spectrum of a compound and one of its components. The investigation of the author was undertaken with apparatus of comparatively small dispersion. Plates accompany the article.—*Annales de chimie et de physique*, Sept., 1888, pp. 1–86. J. T.

10. *A Substitute for Bisulphide of Carbon in Optical work.*—H. G. MADAN recommends the use of phenylthiocarbimide. Its density is 1·35, boiling point 222°. Index of refraction for B and G lines 1·639 and 1·707. It has the same dispersive power as bisulphide of carbon, and can be used in prisms to more advantage than the latter.—*Chem. News*, lvi, p. 257–258, 1887. J. T.

11. *Index to the Literature of the Spectroscope, by Alfred Tuckerman, Ph.D. Smithsonion Miscellaneous Collections.*—This work contains a list of all the books and articles upon the spectroscope and spectrum analysis which have been published up to July, 1887. It contains a bibliography of the History; of the books; of the apparatus; of the analysis in general; of qualitative analysis; of quantitative analysis; of absorption spectra; of alkalies and alkaloids; of astronomical spectroscopy; of carbon compounds; and of the spectra of the metals; together with a list of the authors. The number of titles which the index contains is 3,829 and the number of authors 799. These numbers show how great a service Mr. Tuckerman has rendered to the workers in the field of spectrum analysis. The task of looking up a subject upon which one is engaged is always a laborious one; especially in a subject like spectrum analysis in which there are so many investigators. Few libraries, moreover, contain all the publications in which scientific men of different countries publish their results. One who has run from alcove to alcove and from library to library will take up this index with a sigh of contentment and heartily thank the author.

II. Geology and Mineralogy.

1. *International Geological Congress at London.*—The triennial meeting of the Geological Congress commenced its sessions in London on the 17th of September, and was opened by the Inaugural Address of Professor J. Prestwich, President of the Congress, reviewing the results of former meetings, criticising some of the points in the proposed scheme of nomenclature, and stating the subjects open for discussion. The meeting passed without formal votes on the various questions at issue. The substitution of the term *Ordovician* for Lower Silurian was considered, and appeared to have comparatively little support. It was opposed strongly by Dr. Archibald Geikie, Director of the Geological Survey of Great Britain. Several papers were presented on the nature and origin of crystalline rocks, and abstracts on the papers in full are published in Nature of Sept. 20 and 27, and Oct. 4. The authors of the papers are Professor Ph. Lory, T. Sterry Hunt (holding firmly still, September, 1888, to the Taconian and all his other subdivisions), Professor J. Lehman, Professor K. A. Lossen, Dr. Albert Heim, A. Michel-Lévy, and M. Karpinski. The last four of these geologists brought forward cases of fossiliferous crystalline schists of different periods. These and other papers with a full account of the sessions will appear in the Report of the Congress.

Philadelphia was selected as the next place of meeting, and a committee was appointed to make the necessary arrangements, consisting of Messrs. Hall, Dana, Newberry, Frazer, Gilbert, Hunt, Marsh and Walcott.

From Nature of Oct. 4 we learn that according to the report of Dr. W. Hauchecorne on the map of Europe, four or five sheets of Central Europe will be ready for publication during the next two years and be published without waiting for the rest. The whole number of sheets is to be forty-nine. The scale is 1 : 1,500,000.

American geologists were well represented at the meeting. One of them observes that the Congress, as regards acquaintance-making, opportunity for comparing views and the modes of studying problems in use in different countries, and the discussion of the many problems of international interest was a great success. But "there seemed to be a very general agreement that votes can settle very few of the questions." The American Committee, above mentioned, will have a session at New Haven in November, during the meeting at that place (commencing Nov. 13) of the U. S. National Academy.

2. *Theoretische Geologie von* Dr. E. Reyer, a. o. Prof. der Geol. an der Univ. Wien. 868 pp. 8vo, with 700 cuts and three maps. Stuttgart, 1888 (E. Koch).—The work of Dr. Reyer is based on the recent as well as older results of investigations, and not less those of America than of Europe; and largely upon his own investigations. The subjects discussed include volcanic action and its various results; intrusive sources, conditions, and

consequences ; the various "facies" of sediments and sedimentation over the globe; deformation through pressure and other means, and the attendant fracturing, flexing, compression, faulting; metamorphism of different sources; foliation; and other topics in dynamical geology. The views of the work are those of an independent thinker, whose geological excursions have had a wide range, western North America being included. They are fairly presented, with a recognition of the labors of others, and merit full consideration, if sometimes questioned. The work is well adapted for the student by its clear style and very numerous illustrations.

3. *Les Formes du Terrain*, par G. de la Noë, Lieut.-Col. du Génie au Service Géographique, avec la Collaboration de Emm. de Margerie. Paris, 1888. Service Géographique de l'Armée. 206 pp. 4to, with 48 plates.—The subject of this work is essentially topography as determined by the action of running waters, aided by disaggregating atmospheric agencies, on rocks, differing in kind and firmness, in all their various forms and positions, horizontal, tilted or oblique, flexed, etc. The topics are treated in a systematic way, with great fullness of detail, making the volume a comprehensive review of the methods and results of denudation. They are further illustrated by sketches and sections on the many plates. Part of the facts and illustrations as well as some important principles are taken from authors on Rocky Mountain topography, especially Powell and Gilbert. The volume is a valuable contribution to the science of geology as well as that of physical geography.

4. *The Structure and Classification of the Mesozoic Mammalia;* by H. F. Osborn, Prof. Comp. Anat. Princeton College. July, 1888 (Journal Acad. N. Sci. Philad., vol. ix, no. 2).—Prof. Osborn here gives a very valuable review of the characters and relations of the Mesozoic mammals of America, Great Britain and other countries, with figures illustrating the subject and new facts and figures relating to the American species. The animals were all small, the length of jaw varying from half an inch to an inch and a half. Prof. Osborn sustains the view that they are not all marsupial, but that placental mammals are included, probably the Insectivora or their predecessors, and that marsupial and placental mammals have not successional but parallel genetic relations.

5. *Eozoon Canadense.*—Dr. Dawson, in a paper on "Specimens of Eozoon Canadense" in the Museum of McGill University, Montreal, recently published by the Museum, besides describing specimens, reviews anew the Eozoon question. After mentioning on page 50, his own paper in this Journal criticizing Professor Möbius's memoir on the subject, he observes that "the editor of the American Journal of Science gave Professor M. an opportunity to reply, but stated that he had pledged himself [promised Professor Möbius, on condition of his writing out his views for the Journal] that no rejoinder would be permitted—a

somewhat unfair decision where the case was one of unprovoked attack, and this based on material published by Dr. Carpenter and myself." By referring to Dr. Dawson's article in this Journal for 1879 (vol. xvii) the reader will be able to judge whether Professor Möbius's article six months later (vol. xviii) was an *unprovoked* "attack" or not. It appears to us that the "attack" was first made by Dr. Dawson, if there was any "attack" in the discussion. But we did not regard either paper as an "attack," for each was courteous though earnest. We hold that an honest, courteous criticism is not an attack. It is bad for science that investigators should ever thus regard it; for in that case criticism pretty surely degenerates into attacks which treat opponents as "adversaries."

5. *Nya anmärkningar om Williamsonia af A. G. Nathorst*—(Ofversigt af Kongl. Vetenskaps-Akademiens Förhandlingar, June, 1888. No. 6.)—The discovery described in this preliminary note in Swedish is of the highest interest to geologists and paleontologists. It is nothing less than that the author has found the peculiar inflorescence known as *Williamsonia angustifolia* Nath. attached to the stems and foliage of *Anomozamites minor* (Brongn.) Nath., so as not only to show that the genus Williamsonia belongs to the Cycadaceæ, as long ago conjectured by Williamson, but also to indicate in what manner these flowers were developed in the forks of the sympodial stems of those cycadean plants. A figure is given showing all this, which, however, is admitted to be largely a restoration, and leaves many things to be explained in the forthcoming memoir which is promised. L. F. W.

6. *Riebeckite, a new mineral.*—Dr. A. Sauer has described under this name what he regards as a new member of the amphibole family corresponding to ægirite among the pyroxenes. It occurs in the granite of the island of Socotra, where it was collected by Dr. E. Riebeck. It appears in slender prismatic crystals, black in color, and showing the characteristic cleavage of amphibole. An analysis, after the deduction of 7·12 per cent zircon, yielded :

SiO_2	Fe_2O_3	FeO	MnO	CaO	MgO	Na_2O	K_2O
50·01	28·30	9·87	0·63	1·32	0·34	8·79	0·72=99·98

It thus in composition corresponds closely to ægirite and differs from the arfvedsonite analyzed by Lorenzen chiefly in the state of oxidation of the iron; he found in the Greenland mineral 3·80 p. c. Fe_2O_3 and 33·43 p. c. FeO. The doubt existing as to the true composition of arfvedsonite, however, prevents a definite conclusion as to the relations of the new mineral to it.—*Zeitschr. Geol. Ges.*, xl, 138, 1888.

7. *Mazapilite, a new mineral.*—Dr. G. A. König announces a new mineral from Zacatecas, mining district of Mazapil, Mexico. It occurs in deep red to black crystals, believed to be orthorhombic. The hardness is nearly 7, the specific gravity 3·567. Preliminary trials have led to the conclusion that in composition

it is an arsenite of calcium and iron.—*Proc. Acad. Nat. Sci. Philad.*, July 3, 1888.

8. *The Minerals of New York County, including a list complete to date;* by B. B. CHAMBERLIN.—This little pamphlet, by the late Mr. Chamberlin, is a valuable contribution to the local mineralogy of New York, a subject to which the author had given much attention.

III. BOTANY AND ZOOLOGY.

1. DR. SERENO WATSON'S *Contributions to American Botany.*—The last two numbers of this important series have not yet been noticed in this Journal. For reference the titles are here given. No. 14 contains:—*List of plants collected by Dr. Edward Palmer in the State of Jalisco, Mexico, in* 1886. In this list the Gamopetalæ were determined by Professor Gray, the Juncaceæ and Cyperaceæ by Dr. N. L. Britton, the Gramineæ by Dr. Vasey, and the ferns by Professor Eaton. Proceedings of the American Academy of Arts and Sciences, vol. xxii, pp. 396–485. Also in the same volume, pp. 466–489: a second paper, entitled, *New Species.* These species are about 40 in number.—No. 15, same Proceedings, vol. xxiii, contains [1] *Some new species of plants of the U. S. with revisions of Lesquerella* (*Vesicaria*), *and of the North American species of Draba*, pp. 249–267. [2] *Some new species of Mexican plants chiefly of Mr. C. H. Pringle's collection in the Mountains of Chihuahua, in* 1887, pp. 276–283. [3] *Description of some plants of Guatemala*, pp. 283–287.

G. L. G.

2. *Flora of Middlesex County, Mass.;* by L. L. DAME and F. S. COLLINS, Malden, Middlesex Institute, 1888, pp. 201, with map.—The authors of this work have spared no pains to ensure a good degree of accuracy and completeness. In the first place, they are themselves botanists of experience and have personally examined with great care some of the most interesting portions of the district. And, second, they have availed themselves of the assistance of a goodly number of local collectors, while all important doubtful determinations have been submitted to special authorities. Thus, doubtful Compositæ were examined by the late Professor Gray, Mr. Bebb aided in determining the willows, and Drs. Watson and Farlow assisted at many points by the collections in their charge.

The county is irregular in outline and considerably diversified in surface. Its highest land, Mt. Watatic, in the western part, is somewhat less than 2000 feet above the level of the sea, sea-level being reached at the eastern limit. The county is abundantly watered, and would seem from the map which is crowded with lakes, ponds, and rivers, to promise a rich vegetation, but the soil consists chiefly of the usual deposits and admixtures of gravel, sand, and clay, with which residents of eastern Massachusetts are only too familiar. Hence there are here lacking many

of the New England species which give so great a charm to counties in the Connecticut Valley. The richer soil and longer seasons of districts only a trifle farther west, make a noticeable difference in the vegetation.

A trustworthy list like the Amherst or the Middlesex catalogue is of value to Botany, not only by furnishing to the geographical botanist the data which he requires for his investigations, but also by placing before local botanists a definite task, that of adding to the list. The desire to add to a carefully prepared list of new plants, is neither a slight nor an unworthy stimulus. Middlesex County presents a peculiarity which rather embarrasses local collectors and hence has been very properly noticed by the authors of the catalogue. It contains not only more than its fair share of waifs and strays, but it has within its limits a good many European and Western plants which have been set out in favorable localities in the woods and swamps. A former gardener at the Cambridge Botanic Garden is responsible for numerous cases of this kind, but the most startling surprises are henceforth in store for those who herborise in Concord. There the collector is likely to come upon the most unexpected species growing thriftily. Such are the plants introduced into that town by one of its citizens.

The catalogue is accompanied by a map which presents, by means of a novel method of indicating physical features, a large amount of information within narrow limits. It is to be regretted however that the map was not made on a larger scale, and the book itself of pocket-size.

The authors are to be congratulated heartily on the successful completion of a task which has placed the students of botany within the county under obligations to extend the list. G. L. G.

3. *A Catalogue of Plants growing without cultivation in the County of Nantucket, Mass.;* by MARIA L. OWEN, Northampton, Mass., 1888, p. xi, 87.—The physiographical sketch given in the introduction to this modest catalogue shows clearly why the vegetation of the island may well be full of interest. "Nantucket, as regards its flora, seems like a piece of New Jersey moved up the coast for the convenience of northern amateurs in botany, who cannot get away from business long enough to go collecting in that State." Further, we are told that "Jasmine in the gardens is, in ordinary seasons, in flower from November to February." . . . "The ivy (*Hedera Helix*,) flourishes in the open air without protection seemingly as well as in England, and no limit has been found to its upward growth, except the top bricks of the chimneys to which it climbs."

A climate of such mildness favors a varied vegetation. But almost every other condition is adverse. Therefore one is not wholly surprised to learn from Mrs. Owen's catalogue, that there are less than 500 native species to be credited at the present time to this area of about fifty square miles.

The author states that there are more than 100 introduced

species. Among the more interesting of the plants in Mrs. Owen's list are the following, which occur very sparingly, viz: *Calluna vulgaris, Erica cinerea*, and *Erica tetralix*. The latter grows among imported pines; but, of the other heaths, the author says, "there is nothing in the surroundings, the usual and characteristic vegetation of that part of the island, to indicate accidental introduction." But there can be, we think, no reasonable doubt that these heaths are not native. Under certain circumstances heaths, especially *Calluna*, can in a short time, make themselves much at home in the New England States. With the sterile soil and humid air of the island, it would seem as if they could establish themselves very firmly. But as it is, they have there only a precarious foothold, and require that heed should be paid to the pathetic appeal which Mrs. Owen makes in their behalf. Botanists who go in search of the island rarities which Mrs. Owen enumerates, should aid in defending them from the extinction which now threatens. G. L. G.

4. *Catalogue of the Flora of Vermont;* by GEORGE H. PERKINS, Ph.D., Professor of Natural History in the University of Vermont (from the Tenth Report of State Board of Agriculture), pp. 74. Burlington, 1888.—This list is designed to replace an earlier one by the same author, published in 1882. It has been prepared with great care and is a valuable addition to our catalogues of American plants. Certain parts of Vermont have long been famous as botanical collecting ground, especially Willoughby and Smuggler's Notch. Professor Perkins says rightly, that other portions still wait for the botanist who shall thoroughly explore them. The remarks in the introduction to the list deal to some extent with the rapid changes which are now going on in the vegetation of the State, and the picture which the author draws of the effects of "improvements" is discouraging. The introduction of western and other plants in grass seed is said to have changed the aspect of many acres of meadow-land. "Rudbeckias and Hieraciums have not only appeared, but so increased as when in bloom to change the appearance of the fields in which they have become located." G. L. G.

5. *Plants of Rhode Island;* by J. H. BENNETT, Providence, 1888, pp. 128.—Mr. Olney's Catalogue of Rhode Island Plants was published more than forty years ago, and it appeared to the members of the Franklin Society high time to revise the list. The present catalogue is said by its author to contain three times as many species as the first enumeration, and yet contains, "it is believed, but little more than the half of those species which grow without cultivation within our borders." The latter remark must be taken to apply to the Cryptogamous species, which occupy rather more than half the whole number of pages of the list, and fifty-seven per cent of the total number of species enumerated. Mr. Bennett has been fortunate in securing the services of many collaborators, who have aided in making the list of Cryptogams considerably fuller than that given in any of the local catalogues

which have recently come to hand. It is to be regretted that the localities and the comparative frequency of occurrence are not given for the flowering plants and the fungi, with the same degree of fullness which we notice in the case of the lichens and the algæ.

G. L. G.

6. *Catalogue of the Flowering and Fern-like Plants growing without cultivation in the vicinity of the Falls of Niagara;* by David F. Day, Troy, 1888, pp. 67.—This list was prepared at the request of the Commissioners of the State Reservation at Niagara. It contains besides the species discovered the names of some plants which "may be expected to occur at the Falls," and as the latter appear in the enumeration of the plants actually occurring, they are liable to introduce an element of error into comparisons of the numbers of species found within the limits of the reservation with those given in other catalogues of plants of like restricted areas. The introduction gives a short but interesting account of early botanical exploration near Niagara. G. L. G.

7. *Journal of Morphology.*—The second volume of this excellent Journal was issued in August last. Its 176 pages are occupied by elaborate papers on the Structure of the gustatory organs of the Bat, by F. Tuckerman; on the tritubercular molar in human dentition, by E. D. Cope; on the seat of formative and regenerative energy, by C. O. Whitman; the internal structure of the Amphibian brain, by Professor H. F. Osborn; and studies on the eye of Arthropods, by Wm. Patten. Mr. Whitmann closes his paper with the following paragraphs, pp. 48 and 49.

"The action of the formative power has often been likened to the architectural power displayed in crystallization; and if the essential distinctions are kept in view, such a comparison is justified by one or two very instructive analogies. If the physicist is not compelled to recognize a special crystallizing force, he is at least unable to deny that a crystalline aggregate reacts upon the parts in such a manner as to determine the *direction* of that marvellous 'constructive power' with which the molecules are endowed. When we see a crystal reproduce its lost apex; or, as in the oft-cited experiment of Lavalle, an angle of an octahedral crystal spontaneously replaced by a surface, as the result of an artificially produced surface at the corresponding angle, we have no alternative but to infer a *physical correlation of parts*, under the influence of which the *direction* of forces is determined. So in the development of a germ, in the repair of injured parts, and in the regeneration of lost parts, the fact is irresistibly forced upon us, that *the organism as a whole controls the formative processes going on in each part.* The formative power then belongs only to the organism as a physiological whole; and it does not represent a sum or aggregate of atomic, molecular, or other forces, but results from special combinations of ultra-molecular units, and disappears as such the moment the physiological connexus is destroyed.

"The idea may appear, at first sight, to stand in contradiction

with the fact that parts of an organism, resulting from spontaneous or artificial division, possess the same formative power as did the undivided organism. But it must be remembered that most organisms do not admit of such division, and that in those that do admit of it, everything depends on how the division is made. The extra-capsular portion of a Radiolarian does not reproduce the central capsule, nor does the non-nucleated fragment of an infusorian regain its lost parts. Even here, then, it is not permissible to disregard the physiological correlation of parts, since both nuclear and cytoplasmic elements are indispensable to the preservation of the formative power. We still have to regard such organisms as physiological wholes, although the physiological connexus may be representable in aliquot parts.

"The principle holds true of every organism, irrespective of whether the mass is divided into cells or not. The fact that physiological unity is not broken by cell-boundaries is confirmed in so many ways that it must be accepted as one of the fundamental truths of biology."

IV. Miscellaneous Scientific Intelligence.

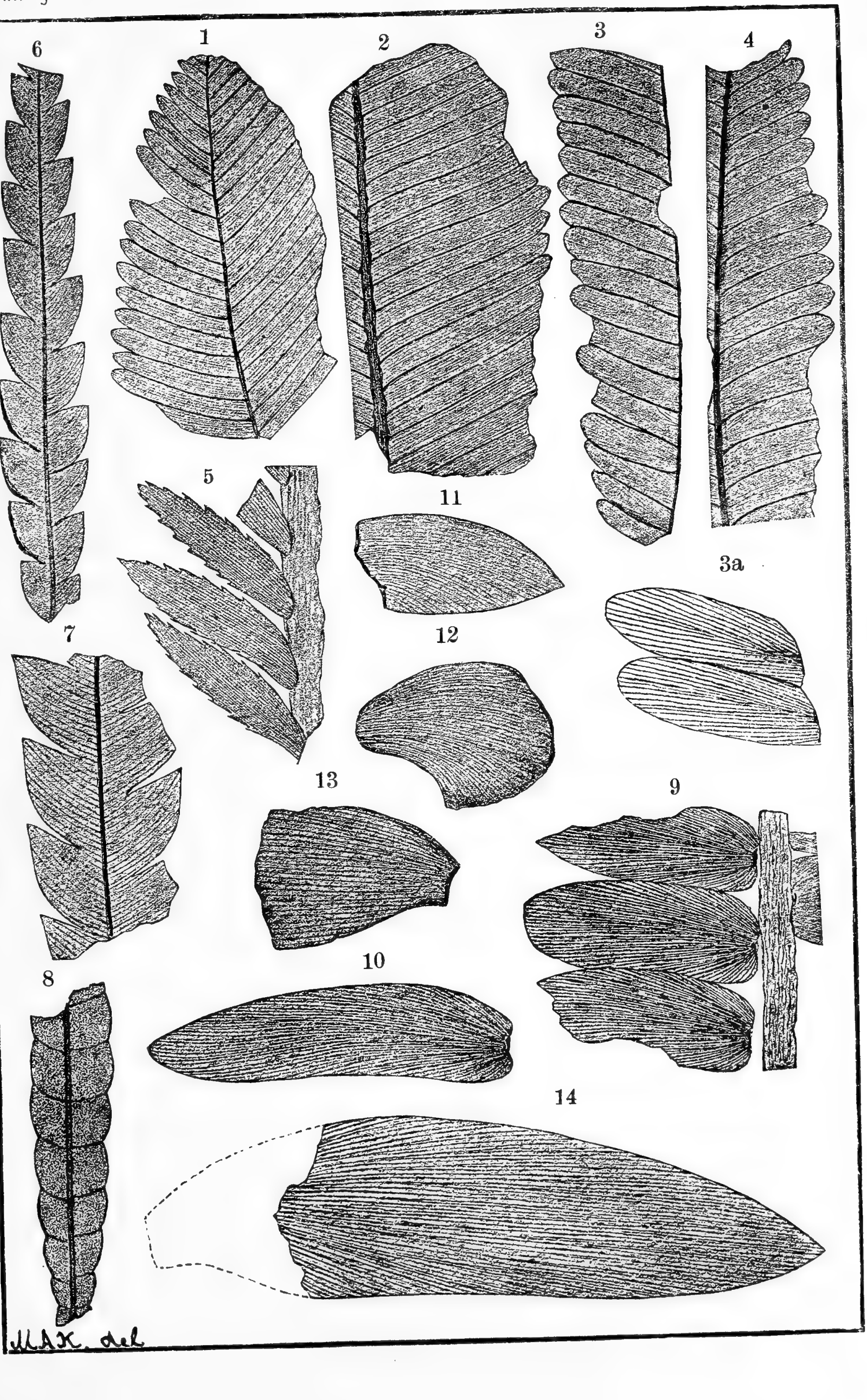
1. *Meeting of the British Association at Bath in* 1888.—The meeting of the British Association opened on the 5th of September, with the inaugural address of the President, Sir Frederick Bramwell. There were Addresses before the several sections on the following day by the Presidents of the sections, Prof. W. Boyd Dawkins, of the Geological section, Wm. A. Tilden, of the Chemical, W. T. Thiselton Dyer, of the Biological, Col. C. W. Wilson, of the Geographical, W. H. Preece, of the section of Mechanical Science, and Lieut. Gen. Pitt Rivers, of that of Anthropology. Probably no geological paper excited greater interest than that of Mr. C. D. Walcott, of the United States Geological Survey, on the remarkable collection of fossils he had made during the summer from the Cambrian beds of south-eastern Newfoundland, leading to a change in the order of succession of the American Cambrian fauna, putting the Olenellus zone at the bottom. A future number of this Journal will contain an account of his important results.

The addresses above mentioned and abstracts of some of the papers presented will be found in the numbers of Nature for the months of September and October.

OBITUARY.

Mr. Benjamin B. Chamberlin, the author of a pamphlet recently published on the Minerals of New York County, died suddenly on the 13th of October, at the age of fifty-seven.

RHAETIC PLANTS FROM HONDURAS.



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as. D. Walcott,
U. S. Geological Survey.

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THE

AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

ART. XLI.—*The Invisible Solar and Lunar Spectrum;** by S. P. LANGLEY. With Plates IX, X.

THE following investigation has been made from studies at the Allegheny Observatory, but it is proper to state that the provision of the very special apparatus used, is due to the liberality of a citizen of Pittsburgh, who has desired that his name should not be mentioned.

This paper is an abstract of a forthcoming memoir, which will eventually appear in the fourth volume of the publications of the United States Academy of Sciences, to which the reader is referred for fuller details.

Ever since the writer first † investigated the infra-red of the solar spectrum to the extent of about three microns, he has assumed, from all analogy, the probable existence of solar heat of still greater wave-lengths, which, however, he has not till lately been able to experimentally demonstrate, so that there has been a doubt whether such waves were emitted by the sun after absorption by its own atmosphere, or whether they existed pre-

* As the writer has already presented to the National Academy a memoir (read October 17, 1884, Memoirs Nat. Acad. of Sci., vol. iii,) on the heat of the moon, in which he spoke of investigations still in progress on it, it should be said that these are not yet published, and that they are only given here so far as is necessary in explanation of certain anomalies in the infra-red solar heat-spectrum, which forms the principal subject of the present paper.

† Comptes Rendus de l'Institut de France, September 11, 1882. Amer. Jour. Science, March, 1883.

viously to absorption by the earth's atmosphere, and, owing to the action of the latter, never reached us. Below the point $2^{\mu}\cdot8$, to which the maps published in 1882 and 1883 extended, it was stated, however, at that time, that there had apparently been detected feeble, or more properly speaking, dubious, indications of solar energy. This doubt arose partly from this extreme feebleness here of the heat itself, partly from lack of the usual experimental means, since the glass of our prisms (which, as we had discovered, transmitted the greater part of all the sun's invisible heat then known) absorbed this, while no maker could then supply its place with suitable rock salt; and, most of all, from a difficulty of a less familiar kind, but which should from its importance be clearly apprehended by the reader. This is, that even if we could recognize that some feeble invisible heat existed, there were then no means of determining that it really belonged to the part of the spectrum where it was found, and was not intruded invisible heat of a more refrangible kind, diffused from its proper place in the upper spectrum by the inevitable defects in the action of spectroscopic apparatus.

In 1884 and 1885, while investigating the invisible spectrum of the sunlit side of the *moon*, we first found evidence of heat in this region from any extra-terrestrial source—heat whose enormous wave-length was comparable to that chiefly radiated from ice, which was also experimented on. This was so far distinct from the reflected solar heat of greater refrangibility, which occupied its own part of the spectrum, that our experiments indicated that this lunar heat was mainly not reflected, but radiated from a surface at a low temperature. But the chief anomaly was that while we had thus definitely recognized this kind of heat in the extremely feeble heat-spectrum of the moon, we had not yet done so in the far stronger solar one, or, as I observed at the time, that "we here *seem* to have heat from the moon of lower wave-length than from the sun."

I do not state (it must be observed) that the sun's heat here is less than the moon's, but that what there is is harder to recognize. It is not easy to give an adequate idea of the difficulties of observation which lead to this apparently paradoxical result, particularly as physicists are so far from having yet investigated this region that even the barriers which have closed it to research are themselves of an unfamiliar kind. I can perhaps best illustrate it by analogy. Every spectroscopist knows how very hard it is to view the lines below A, and that even A itself, though very large, is not an easy object to see without special precautions. This arises not so much from the fact that the very deep red light here, like that of dull glowing iron, feebly effects the eye, but, in a still greater degree, because

yellow and orange light exists in relatively enormous quantity in the neighboring parts of the visible spectrum, and irregularly diffused and reflected portions of this light re-appear where they do not belong and overpower the radiation legitimately there. Still, we can put a colored glass before the slit and cut off the intruding light in a great measure, and we can *see* the extraneous light which comes in, and allow in some degree for its effects; but here, in the actual case of the unseen heat in the far more remote spectral region we are about to describe, all radiations, both the feeble ones we would study and the intruders on them which we would avoid, are alike invisible, and we are, of course, unable in any case to use glass, since this is opaque to all the rays now in question. If any one familiar with the visible spectrum will imagine himself as trying to discriminate with his *eyes shut* between these different components of the apparent radiation just below Fraunhofer's A, and endeavoring while blindfold to say how much of it legitimately belongs there and how much does not, he will have a better conception of the difficulties peculiar to our actual field of research, though still an inadequate one, since the total heat radiation here is at best less than the hundredth part of that in the vicinity of the A line, which we have used in illustration.

For the clearer understanding of this, I must, in anticipation of what follows, remark that while in the solar spectrum the maximum heat, as we all know, appears not very far from the red, so that the heat corresponding in a general sense to the short waves is great, and to the still longer ones small, in the lunar invisible spectrum the reverse is the case; for here, speaking generally, the solar reflected heat found in the upper part of the lunar spectrum is less than the heat apparently radiated from the moon's own soil, which is of great wave-length, and which we have found in the extreme region of the spectrum we are now studying. In other words, the typical solar spectrum heat is greatest in the relatively short wave-length; the typical lunar spectrum heat is greatest in the long wave-lengths. The explanation of the curious fact that this particular quality of heat may be more easily recognized where it exists in a less degree in a lunar spectrum than where it is found in a relatively great degree as in the solar, will be still clearer if we consent (in continuance of the illustration) to further compare this lunar invisible radiation of great wave length to the deep-red light from a piece of scarcely luminous hot iron. This peculiarly deep red is seen with little difficulty in the iron in a dark room, but never in daylight; yet it is of a quality which we know from theory must exist in far greater degree in the daylight itself; nor do we, even when we would isolate it in a certain part of the solar spectrum, see it there,

because it is now obscured by the inevitable diffusion or reflection of part of the neighboring brilliant light which the prism ought to keep wholly away, but (owing to inevitable instrumental defects) does not. The dull glowing iron carries no white light along with it, and therefore its feeble peculiarly deep red is easier seen than the far stronger corresponding red in the solar spectrum.

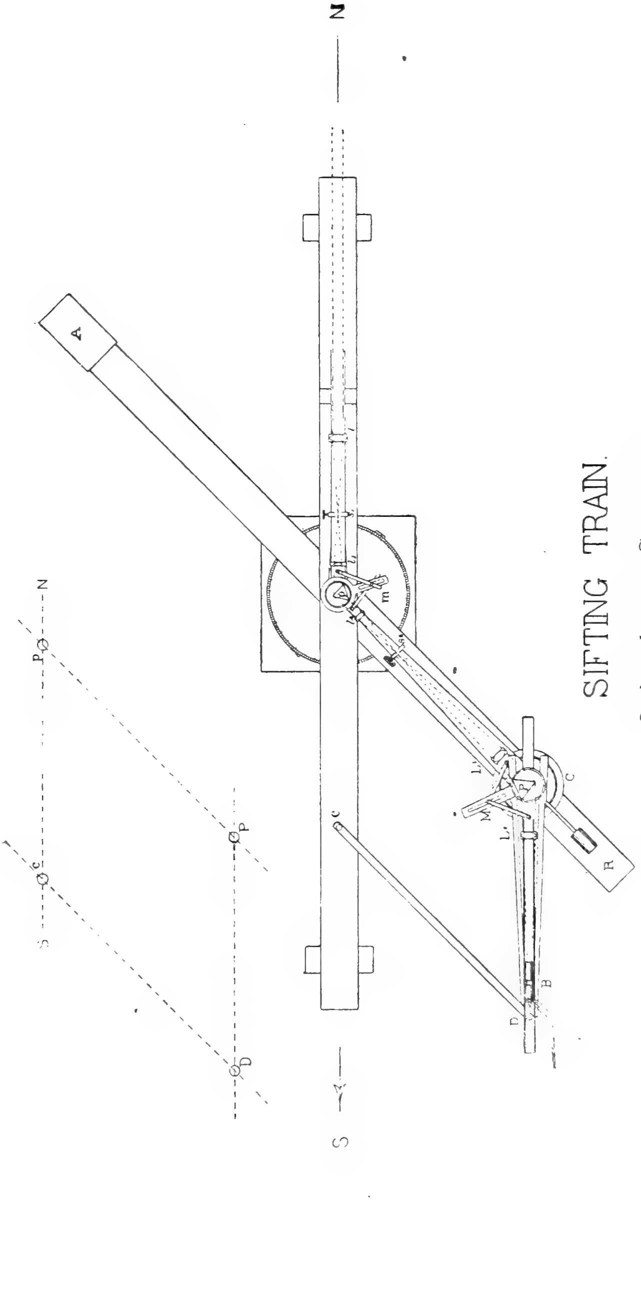
By the aid of this analogy in the case of light, and passing now to the actual case of wholly invisible radiation, I hope it may be clear how the feebler heat in the lunar extreme infra-red spectrum was at first recognized more easily than the stronger corresponding heat in that of the sun.

It may be asked why (if we cannot cut off the diffused heat in the solar infra-red spectrum by the use of an absorbing glass) we cannot put a prism in front of the slit after the plan of Helmholtz. This is practically impossible here (owing to instrumental conditions which we need not now explain), unless we find some way of keeping the axis of the spectro-bolometer either motionless or always parallel to itself, in spite of the varying direction of the rays from such a prism, and of automatically limiting the kind of radiation to be observed in any part of the spectrum, to that legitimately belonging there. The following arrangement was, after various trials, adopted with success. Its immediate purpose is to overcome the difficulty which we have just explained at such length; that is, to sift out the extraneous heat which remains after the ordinary action of the prism, but it can of course be used for light also.

Description of Sifting Train. (See fig. 1.)

Let N S be a massive beam, resting on two piers, and immovably fixed in the meridian. Let A R be a second beam, movable on a turn-table, placed centrally beneath N S. Temporarily mounted on A R, and moving about with it, is the large spectro-bolometer described in a previous memoir. The center of its graduated circle (C) lies under the point P. Its two long arms are not free to move as usual, but are constrained by mechanical attachments (not here shown) to occupy the positions P*p*, PD.

Two large 60° prisms of the same material (pure rock salt from the same mine), their faces worked with the greatest accuracy, are placed with these equal refracting angles in opposite directions, one (P) at the obtuse, the other (*p*) at the acute angle of the parallelogram (P*p* D*c*), the vertices of all whose angles in the mechanical construction are pivoted and connected by inflexible arms, so that (both prisms being kept automatically in minimum deviation by the attachments M, *m*) the angle of minimum deviation (*c p* P) for the first prism is



SIFTING TRAIN.
Solar-Lunar Spectrum.
FIGURE 1.
S.P.LANGLEY.

necessarily equal to the angle of minimum deviation (R P D, or its equal P D*c*).

Thus, if the pencil of solar radiation reflected from a large siderostat on the north, not shown here, passes from N toward S, on moving the beam A R, pivoted at p (p being the projection in our drawing of a vertical line passing through the center of the turn-table and the median line of N S and A R) into various positions, N S remaining fixed, the rays, which are refracted by the prism p in the direction of p P, will emerge from P in the direction P D and fall upon the bolometer B. A condensing lens (l) forms the solar image on the slit (s_1) of the first spectroscope, whose train (consisting of collimator, l_1, prism, p, and image-forming lens, l_2) forms a spectrum on the slit (s_2) of the second spectroscope. Here a narrow pencil from the first spectrum comprising *only* the particular wave-lengths which fall within the width of s_2, is admitted, and, by the second train L_1 P L_2, formed into a horizontal spectrum at and on either side of B. When we move A R this spectrum moves in turn past the vertical linear thread of the bolometer B, which lies in the focal plane of this spectrum, and is immersed in its successive absorption lines as these defile past it. The function of the first spectroscopic train (l, l_1, p, l_2) is solely to sift out the extraneous radiations and to present at the second slit (s_2) only those which legitimately belong to that part of the spectrum we wish to study. These pure rays pass into the second slit and are analyzed by the second train in the usual way, by the aid of the linear bolometer at B, and of the circle (C) reading to ten seconds of arc.

The objection to this apparatus is its complexity, which, however, we have been unable to advantageously diminish. We may, however, satisfy ourselves by visual observation of the Fraunhofer lines seen through the whole compound system; (entirely of salt) both of the optical perfection of the surfaces of our entire double train, and of the accuracy of its purely automatic action.

Results of Observation.

With this and the apparatus already described in previous memoirs we have searched the extreme infra-red solar spectrum at first without definite success, later with results which will be better understood by the accompanying drawings.* Fig. 2*b* shows the newly investigated invisible solar heat spectrum on the normal scale up to an (estimated) wave-length of 18^{μ}. Fig. 3*a* is an enlarged view of that portion of it, extending to 5^{μ} and fig. 3*b*, a photographic interpretation of the last, obtained automatically by a special device; so as to present somewhat

* For figs. 2*a*, 2*b*, 3*a*, 3*b*, see Plates IX, X.

the appearance which this heat region might be expected to show to an eye which could see it.

Inordinately long as our new chart fig. 2*b* may seem, we see that the scale is, nevertheless, contracted to the last degree, so that the entire visible spectrum is compressed into less than 0.2 of an inch, seen on the left or violet end. Next we have the solar infra-red, already described and shown to exist to $2^{\mu}\cdot 8$, which includes its great absorption bands, Φ, Ψ, Ω, previously investigated with glass prisms.

The principal lunar heat lies chiefly beyond the great wave-length of $0^{mm}\cdot 01$ (10^{μ}), and ere we reach it we pass over a region between 5^{μ} and 11^{μ} (many times the length of the entire visible spectrum), where the solar heat seems to have been, to our present means of recognition, entirely absorbed, probably chiefly by our own atmosphere.

It will be convenient, however, after noting the extent of the whole region shown in fig. 2*a*, to commence our description with the detailed portion shown in figures 3*a* and 3*b*, to which the reader is referred in illustration of what immediately follows.

The lowest bands already described, as seen in the spectrum of a flint glass prism, are the small ones ω_1, and ω_2, near 2^{μ}. Below this point all is believed to be here given for the first time. The bands in this new region are undoubtedly due, chiefly, if not wholly, to telluric absorption, and they are notably variable, depending on the season of the year and still more on the hour of the day. As the sun sinks, its rays, passing through increasing air masses, suffer absorptions which singularly change the appearance of the bands; as is shown in figures 4 and 5 which, however, are drawn upon the prismatic, not the normal, scale. Figure 4 is identifiable with the portion extending from X to Y on the latter.

Observations made during the winter indicate that the band at $2^{\mu}\cdot 64$, figures 3*a*, 3*b*, is, with a high sun, largely filled up, especially on the less refrangible side. At noon a subordinate maximum has been found within the low sun limits of this band at $2^{\mu}\cdot 94$, and a second one at $2^{\mu}\cdot 80$ frequently accompanies it, producing subordinate minima at $2^{\mu}\cdot 89$ and $3^{\mu}\cdot 02$. As the absorption increases, with a sinking sun, these subordinate maxima disappear to a very great extent, that at $2^{\mu}\cdot 80$ being the first to vanish as well as the quickest to grow, so that at noon, on a cold day, it not only surpasses the maximum at $2^{\mu}\cdot 94$, but even begins to approach that at $3^{\mu}\cdot 20$, while, when the sun's altitude is less than 10° the nearly uniform

part of the band extends from $2^{\mu}{\cdot}45$ to $3^{\mu}{\cdot}15$ without a break. Minor cold bands at $3^{\mu}{\cdot}37$ and $3^{\mu}{\cdot}69$ are suspected. The evidence for their existence may be seen by inspecting the high sun and low sun curves given in fig. 4. From $4^{\mu}{\cdot}0$ to $4^{\mu}{\cdot}5$ we have another region of almost complete absorption, followed by a maximum at $4^{\mu}{\cdot}6$, beyond which lies the longest break of all, stretching from 5^{μ} to 11^{μ}. The solar heat throughout the region from 5^{μ} to 11^{μ} is probably far greater than it here appears, and if the parts struck out by our atmosphere were restored it would probably be found that a not wholly inconsiderable portion of the sun's heat lies in this region, for it must be borne in mind that even the maxima are doubtless in some degree affected by a linear absorption, so that, because a part of the spectrum appears to be almost entirely transmitted, we cannot infer that it necessarily is so, or that it has not, after passing through the upper strata of the air, already parted with a considerable portion of its energy. While the position of a line or band caused by light from the center of the sun is, in the upper spectrum, unchangeable, in this extreme lower spectrum (if we could photograph it, like the upper, on cold and on hot days, with high sun and with low), the absorption would be seen to increase, not symmetrically with the center of the band, but more on one side than another, so as to considerably modify the position of greatest absorption. This seems to be the explanation of a curious fact, which could not have been anticipated in advance of observation; that is, that the centers of several of these bands and lines are under some conditions found to be shifted to a recognizable extent, and hence their wave-lengths are, within certain limits, variable.

It seems as though the absorption, which we see exercised in most of the visible spectrum by fine lines, which begin already to show aggregation into a broader absorption band on the borders of the infra-red (*e. g.*, the well-known "A" of Fraunhofer), is, as we pass farther down into the invisible part, represented by wider and wider bands, like Φ, Ψ, Ω (composed themselves of lines probably). The heat between these local regions of almost total absorption continues, as I have repeatedly before stated, to be (contrary to the old belief) apparently transmitted with even greater facility than that in the visible spectrum. These bands have grown larger, and closer and closer together, as we have come down from the visible spectrum below the point where the old map ended, and not far below 5^{μ} they seem to practically coalesce into one almost unlimited cold band. We do not, let it be observed, assert that the absorption is absolutely total even here, and, in fact,

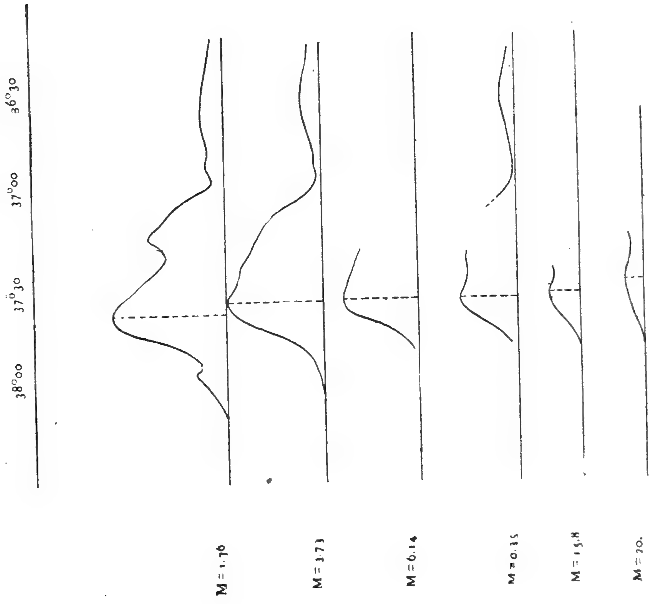


FIGURE 5. Absorption and Air Mass.
Allegheny Observatory, February 19th, 1887

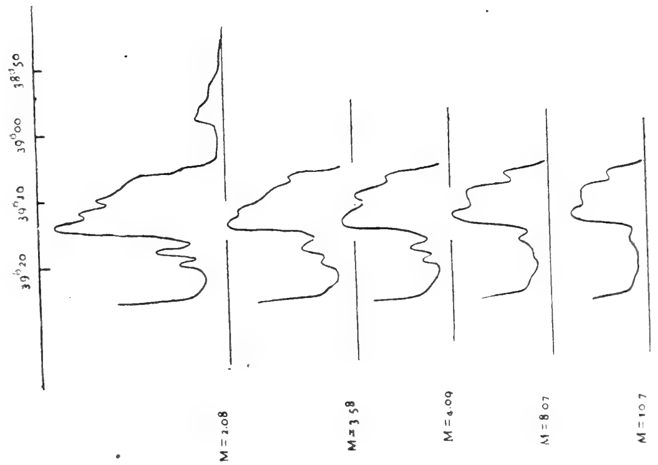


FIGURE 4. Absorption and Air Mass.
Allegheny Observatory, January 22d 1887

there is always a feeble heat to be observed throughout this extent. This, however, the use of the sifting train shows to be largely, at any rate, factitious, but we admit the possibility that subsequent research may prove that it is not all so.

Let us now recur to fig. 2*b*, where we shall find below 10^{μ} the same dependence of the effects upon the season and the hour, as in the part above 5^{μ}. At $10^{\mu}{\cdot}2$ observations made during the autumn showed scarcely the feeblest suspicions of heat, and the same has held good in the very mild weather of the past winter (of 1887); but on a few days, when the temperature had fallen below the freezing point, a notable maximum was found at this point, followed by a minimum at $10^{\mu}{\cdot}7$. The height of this maximum relatively to the principal one in this region at about 13^{μ} appears to be correlated with the composition of the air as affected by the temperature. On the coldest day (temperature at noon—6·7° C.) the deflection at midday for $\lambda = 10^{\mu}{\cdot}2$ was nearly one-half that at 13^{μ}, but on other days, when the temperature was near 0° C., the deflection at $10^{\mu}{\cdot}2$ did not exceed one-fourth that at 13^{μ}, while at temperatures above +10° C. it was not noticeable.

It is in the region near 13^{μ} to 14^{μ}, or over twenty times the length of the visible spectrum below it, that we have found the maximum of the lunar heat spectrum, and it is here that we first obtained indications of solar radiation corresponding in its great wave-length to this special lunar radiation, but of amounts non-estimable by the means till now employed. I have already spoken of its almost unrecognizably small amount, and a perhaps more vivid apprehension of its extreme minuteness will be gained from the statement that on this graphical construction, on the scale of ordinates used in delineating the curve from 0 to 5^{μ}, no heat appears below 5^{μ} anywhere, not even at the maximum near 13^{μ} and 14^{μ}; because, though heat exists to the bolometer, the highest ordinate which would represent it on our drawing is not so great as the *thickness* of the thin black line, which denotes the axis of abscissæ. I have accordingly here been obliged to exhibit it separately by a dotted curve whose ordinates are one hundred times those in the remainder of the spectrum. The points of minima in it are identifiable with absorption bands, which we have directly observed, and which we have independently found to exist in our own atmosphere, by studying the radiations from a copper surface, one meter square, at the temperature of boiling water placed in the open air at a distance of one hundred meters from the bolometer. (The description of this will be found in

a supplementary research to be given elsewhere.) The principal lunar heat then is found here, at a point of the spectrum corresponding to the maximum radiations from melting ice, but its maximum amount is probably less than 1 per cent of the corresponding solar heat, which we have just found to be itself so small. That we can detect the lunar heat at all under these circumstances is due to the fact that we are here able to employ for it very short-focused mirrors and lenses, which condense it into a very short and relatively hot spectrum (there being no fear of their diffusing extraneous heat, since none worth mention exists). In the case of the sun we must employ a wholly different optical train, forming a far longer spectrum. It will be easily understood that these means, which enable us to determine the position of the solar and lunar heat maxima here are not favorable to a determination of the relative amounts of heat received from the sun and moon under such different conditions. We can only say that these ratios are themselves utterly changed from what they are in the visible spectrum, where we all know that the solar *light* is something like five hundred thousand times moonlight. It is probable that the solar heat received in *this* part of the spectrum is less than five hundred times the lunar; but the actual ratio is only very roughly determinable by our present means.

By comparison with the "heat" spectra given in a previous memoir, we may also note the fact that some of the wave-lengths given from ice, are identifiable in the solar spectrum, nor (in view of the now established fact that the *ratios* of the heat, at like parts of the spectra of two unequally hot bodies, are functions of the wave-length) need it surprise us, that we have also found that this part of the spectrum of the sun, is not incomparably hotter than the corresponding part of the ice-spectrum.

It may be asked if we can, after all, feel sure of the character of such minute amounts of heat in the presence of the already described reflected and diffused heat from the upper spectrum, considering the possibility that something may go wrong in the elaborate arrangement of the sifting train, and leave us (as everything we study now is invisible) without ocular warning of the fact. I may reply that we have lately found an admirable check upon the efficiency of our optical devices in the behavior of that familiar substance lamp-black, which all physicists use either on thermometers, thermopiles, or bolometers. All of us know probably that it is not absolutely non-selective, as it used to be thought, and that it has a tendency to transmit the infra-red with greater freedom than the visible spectrum, but the statement I am about to make may excite surprise. It is, that when a very perfectly polished

rock-salt plate is covered by a sheet of lamp-black of such thickness as to transmit less than one per cent of ordinary white light, it transmits about 90 per cent of the radiations belonging to these extreme wave-lengths. In other words, it has become a transparent body to rays of this wave-length, while it exercises an intermediate degree of absorption on intermediate rays, so that by the amount of their absorption by lamp-black, we have a test by which these latter may be independently identified.

We have given the preceding study not only to map new lines and bands in the region between 3^{μ} and 5^{μ}, but also to verify the existence of an all but infinitesimal amount of heat at much greater wave-lengths. We have applied great pains to this latter, not so much on account of its own importance, as on account of the important conclusions to be drawn from it later; for if it is true that in this extreme spectral region, corresponding to temperatures much below the boiling point and even below that of melting ice, the amount of the solar heat is trivial, it is also true that the fact of its existing at all is of very significant interest to the meteorologist; for it is obviously here, at temperatures below 100° C., that the rays which make up the nocturnal as well as diurnal radiations from the soil of our own planet are to be found. We observe that if such rays can enter the air from the sun, they can go out even from an icy soil (and still more from an ordinary one), to whose radiations it hence appears the atmosphere is not unpermeable. Heat, then, apparently escapes in some very minute degree even from the surface of the Arctic Zone, not only by convection but by direct radiation through the atmosphere toward space. Meteorological questions of great interest, to which we shall return in a later memoir, can best be answered from a study of this spectral region, and even if the problem of the lunar temperature did not interest us as students of celestial physics, we should still find others depending on it of very practical import.

As to the degree of accuracy obtainable in fixing its position in the spectrum, we may remind the reader that the old formulæ of Cauchy and others being useless, as we have shown, we have already undertaken a research* to enable us to determine such wave-lengths in this region. We have determined all the wave-lengths by the interpolating curve made from the observations of 1887, which has been exhibited to the Academy at its April meeting. In this memoir will be found all the explanations we can offer relating to the degree of trustworthiness of the values assigned to the present extreme wave-lengths. If they are, as we believe, to be trusted within the limits there given,

* On hitherto unrecognized wave-lengths. This Journal, August, 1885.

we have measured indications of lunar heat (and possibly of solar) greater than are shown on this drawing, and whose wave-lengths exceed one-fiftieth of a millimeter. It is not likely that the more refrangible of that extremely feeble heat, which we here particularly describe, is much less than 11^{μ}.

I think we may now feel justified in saying that we probably know some of the main facts about the solar spectrum, so far as terrestrial absorption is concerned. Broadly speaking, they are these:

Hardly one-fourth of the solar energy, as we receive it, is visible, at least without special precautions. Of the remaining three-fourths, far the larger portion of the heat actually received lies in the region above $2^{\mu}{\cdot}8$, which has already been delineated, but if it were not for terrestrial absorption, the heat in the region below it would be relatively so much greater, that it is probable that of the original solar energy, before absorption, *more* than three-fourths is invisible.

The effects of terrestrial absorption appear in the visible spectrum chiefly by means of the telluric Fraunhofer lines, so that our first impression on looking at it is that these lines only occasionally interrupt the play of light and color by which the solar energy makes itself known through the sense of vision. As we go down into these lower parts of the infra-red region, we find (directly contrary to the old belief) that, broadly speaking, the radiation apparently grows more and more transmissible by our atmosphere, and this because *the heat rays between the lines* grow more and more transmissible, while the lines themselves, though growing into broader bands of almost total absorption, have not yet extinguished the hot regions between them, so that, even taking regions of transmission and absorption together, on the whole here, i.e. above 3^{μ}, more of dark heat in proportion seems transmitted than of light heat. We may roughly illustrate* this portion of the sun's spectrum after absorption by saying that if it were visible, it would present almost the appearance of diffuse luminous bands on a dark field, somewhat like those seen in the spectra of stars of the fourth type. As we have observed that absorption seems to increase in the same direction in the sun's own atmosphere as in ours, it would be interesting to know if anything analogous exists in the absolute solar spectrum; i. e., before absorption in the sun's atmosphere, but this we are not as yet able to determine.

Since, in the part of the spectrum described here for the first time, the same process of aggregation into ever wider and

* Figure 3.

wider regions of absorption is continued till these intermediate regions of transmission disappear, the whole, to repeat an expression I have used in an earlier memoir, seems to become one continuous cold band, in which, however, we have found a little heat struggling through in the part beyond 11^{μ}. Briefly, then, we may say, that to an eye which could see the whole spectrum, visible and invisible, the luminous part being, as we know, interrupted by occasional dark lines, the lower part to 5^{μ} would appear to consist of alternate bright and dark bands, and the part below 5^{μ} be nearly dark, but with feeble "bright" bands at intervals. In conclusion, we may say that these new researches extend the known solar spectrum from three to much over the eighteen microns, shown on our plate, and while confirming the previously announced fact that the solar heat of the great wave-lengths which actually reach us is negligible in amount, show from the fact of the existence of any at all, that the anomaly of our being able to perceive lunar heat where we could not formerly detect solar, can be explained consistently with the possible existence of the latter of every wave-length before absorption.

These investigations into a problem of Solar Physics have also incidentally led us to the prospective means of solution of an important one in Meteorology, for they have opened to observation the hitherto unknown region of the spectrum, in which the nocturnal and diurnal radiations not only from the moon toward the earth, but from the soil of the earth toward space, are to be found and may be hereafter studied in detail.

Art. XLII.—*A brief history of Taconic ideas*; by James D. Dana.

As the Taconic controversy is now nearing its end, a brief review of the progress of ideas relating to the various sides of the subject from the time of the earliest discussions to the present will be found instructive.*

* A historical account of the Taconic, especially of the views of Taconic advocates, entitled "The Taconic System and its position in Stratigraphical Geology," by Mr. Jules Marcou, is contained in the Proceedings of the American Academy of Sciences, vol. xii, 1884, 1885, pages 174 to 256. It relates mainly to the "Upper" Taconic, and makes little mention of facts or observations of the thirty years past connected with the "Lower" Taconic rocks in the southern half of Vermont, Massachusetts with its typical Williamstown Taconic section, and in eastern New York from Rensselaer Co. southward; all which have a profound bearing on the question of age, and on the true relation of the "Upper" and "Lower" sections. No account is given of the Taconic system of 1842, in the detailed presentation of which Prof. Emmons states its fundamental and distinctive

1818 to 1828.—The name Taconic first came into topographical geology through Professor Chester Dewey, who made the earliest geological map of the region, observed the general arrangement and eastward pitch of the beds, and called the rocks in the style of the time, Transition rocks.*

Prof. Amos Eaton gave credit in 1820 to Prof. Dewey for the chief part of his knowledge of the Taconic rocks;† but, by 1828, this pioneer in American geology had made fifteen sections of the rocks from the Hudson River to the Taconic mountains, in order to ascertain, as he says, their conformability and true order of succession.‡

1836 to the close of 1841.—Prof. Emmons, whose department in the New York Geological Survey covered the northern and northeastern part of the State, and who was already acquainted with the adjoining region of Williamstown in Massachusetts, continued his survey into Williamstown. But in the New York Annual Reports no mention is made of the Taconic system either by him or by any other of the New York geologists. This is true even of the latest—the fifth—annual Report, that for 1840. Prof. Emmons, in his part of this Report, under the date of transmittal of Feb. 1, 1841, says on page 94:

"The Granular quartz of Bennington, which occurs also in Dutchess Co., N. Y., I believe to be Potsdam sandstone in a metamorphic form, and the granular limestone associated, to belong to the same geological epoch." I believe "that the rocks from Lake Champlain, along the eastern part of the counties of Washington, Rensselaer, Columbia, Dutchess, all of Putnam, Westchester, great part of Rockland and southeast part of Orange are metamorphic and intruded rocks, and I would suggest that all the rocks from the New York state line to the Connecticut valley are similar. The talcose and micaceous and talco-micaceous divisions of the Green Mountain range in Vermont, Massachusetts and Connecticut have a strong analogy to the metamorphic slates of the east part of Washington, Rensselaer and Columbia Counties, but are traversed by large granite veins and are interstratified with intrusive rocks which might be expected to produce a greater change in mineral constitution."

characteristics, and to which alone the discussions in 1842 to 1844 by Rogers, Mather, Hall and Hitchcock had reference. Mr. Marcou's own special Taconic investigations were made in northern Vermont and its vicinity, a region barely alluded to as Upper Taconic by Prof. Emmons.

* C. Dewey, this J., i. 337, 1819; ii, 246, 1820; viii, 1, 240, with the map, 1824.

† A. Eaton, Index to the Geology of the United States, 1820.

‡ A. Eaton, this J., xiv, 147, 1828, where he says: "I have traversed the Transition range from Massachusetts line to Hudson River in fifteen places, since the first part of my survey was published, for the purpose of ascertaining the true superposition of rocks in this most complicated and difficult geological theatre." Prof. G. H. Cook recently drew my attention to this statement of Prof. Eaton which I had previously overlooked.

As late, then, as February, 1841, there was no indication that the Taconic system had taken shape in the mind of Prof. Emmons, although pretty well stored with Taconic facts. In opposition to the ideas of the Taconic system of 1842, the quartzyte is spoken of as the "Potsdam sandstone" in a metamorphic state, and the associated granular limestone as of "the same geological epoch."

In 1842, the quarto Report on New York Geology by Prof. Emmons appeared, with its letter of transmittal dated January 1, 1842; and in this volume the account of the Taconic system as a new system of rocks in American geology covers pages 135 to 164, thirty quarto pages. The germinant period was, consequently, between February 1, 1841, and January 1, 1842.

Another fact brings us closer to the time of first announcement. The system became a subject of special discussion, as I am told by Prof. James Hall, at the meeting of the American Association of Geologists and Naturalists held early in April, 1841, at Philadelphia. This narrows down the germinating period to the two months between February 1 and April 10 of 1841.

Those who took a prominent part in this first discussion were Professors Henry D. Rogers, Edward Hitchcock, Wm. W. Mather, Mr. James Hall and Mr. Lardner Vanuxem. Prof. Rogers was interested in the subject because of his elaborate geological study of the Appalachian Mountain system on which he reported at length to the Association the following year; Prof. Hitchcock, because the heart of the Taconic region was within his own field of study—the state of Massachusetts,—his final report on which he already had in the press; Prof. Mather, because part of the Taconic rocks west of Massachusetts were very largely within his section of the survey of the State of New York; Prof. Hall, because of the bearing of the facts on the system of New York rocks. Prof. Vanuxem, also one of the New York State geologists, had under his charge only southern New York west of the Taconic area and had given the rocks no study.

Although we have no report of the discussions,* we learn from later publications that Professors Hitchcock, Rogers, Hall and Mather objected to the views of Prof. Emmons, and Mr. Vanuxem † favored them.

* The Proceedings of the meeting in this Journal, xli, 158, 1841, and in the Trans. Assoc. Am. Geol. and Nat., 1840–42, contain no allusion to the discussion, discussions being, as the Preface of the Transactions states, "imperfectly reported in these pages." The only fact of any Taconic interest mentioned in the Proceedings of the meeting for 1841 (Proc. Assoc., 1883, p. 16, and this J., xli, 163), is that of the occurrence of impressions of Annelids in the slate of Waterville, Me., by Prof. O. P. Hubbard—the fossils and slates being afterward (1844) claimed for the Taconic by Emmons. Prof. Wm. B. Rogers did not become a member until 1842.

† Mr. Vanuxem has a page on the subject in his N. Y. Geological Report, p. 22.

The comparison of views at the meeting resulted in inducing Prof. Rogers and Prof. Hall to take the field for the study of sections over the Taconic region. The season had just passed when Prof Rogers made a report on his results to the American Philosophical Society at Philadelphia,* sustaining the views which Hitchcock, Hall, Mather and himself had before favored, namely: that the rocks were Lower Silurian (as the term was then used) from the Potsdam upward, but much flexed and disguised by partial metamorphism. Prof. Emmons mentions in his Report of 1842, on p. 147, that "Professors Hitchcock and Rogers" were prominent objectors to his views. We learn that Prof. Mather's views were essentially those of Prof. Rogers from his New York Geological report published in 1843. In his Preface he gives an interesting account of the discussion. The Dr. Dana he refers to was Dr. Samuel L. Dana, of Lowell, Mass.

1842 to the close of 1844; Phase I.—Such was the state of opinion when Prof. Emmons's full report on the Taconic system was published in 1842.

The Taconic system of this report comprised the rocks from the Hoosic Mountains westward, passing over the Hoosic Valley, Saddle Mountain (which included Greylock), and also over the high ridge of granular quartz, Oak Hill, just north, the Williamstown plain, the Taconic Mountains next west on the Massachusetts boundary, and the eastern border of New York west of this boundary to the Hudson. Beginning on the east, the rocks were: (1) the "Stockbridge limestone," (2) the "Granular quartz" and the "magnesian slate" of Greylock, which are topographically north and south of one another, (3) the limestone of Williamstown plain, (4) the "magnesian slate" of the Taconic mountain, (5) the "sparry limestone" west of the latter, and farther west, (6) the "Taconic slate." The following, commencing at the bottom, is the chronological order according to Emmons, and in a parallel column, are given the true equivalents (the Roman numerals giving the order of age) as established by the latest investigations.

	Taconic System of 1842.		*Equivalents.*
6.	Stockbridge limestone.	II.	Lower Silurian.
5.	*a.* Magnesian slate of Greylock, perhaps a repetition of No. 3.	III.	Hudson slate.
	b. Granular quartz.	I.	Cambrian.
4.	Limestone.	II.	Lower Silurian.
3.	Magnesian slate of Taconic Mountain.	III.	Hudson Slate.
2.	Sparry limestone.	II.	Lower Silurian.
1.	Taconic slate.	III, I.	Hudson slate and Cambrian.

* Proc. Amer. Phil. Soc., Jan., 1842.

The order of succession adopted by Emmons was the order of superposition, as he states, with arguments in its favor, on page 147 of his report, the idea of flexures being rejected. The granular quartz he says (p. 138) "lies between two masses of limestone,"—which is topographically a fact.

The idea of the pre-Potsdam age of the beds was based on the absence of fossils; on the difference in the kinds of rocks, and in their succession, from the lower rocks in the New York series; also on supposed unconformability, no special case however being mentioned. He says, with reference to the distinction in kinds of rocks (p. 139), "As a general rule, certain minerals are found in particular rocks; and may not a similar rule or law prevail where a system of rocks is concerned?"

Early in May of 1844, two years after the appearance of Prof. Emmons's Report and over half a year before his second presentation of the system, Professor H. D. Rogers brought the Taconic question into his Presidential address before the "Association of American Geologists and Naturalists," and reiterated his former conclusions.*

1844 to the close of 1849; Phase II.—In December, 1844, appeared as a pamphlet in 4to—the preface bearing the date December 2, 1844—Prof. Emmons's revision of the Taconic system, with additions and an extension of its limits; and in 1846, the same was published as a chapter in his N. Y. Report on Agriculture. The prominent changes are the following: (1) the system is, for the most part, turned the other side up, Rogers's views being adopted as to flexures and overthrust folds. (2) It is made in part fossiliferous, and the fossiliferous part is put at the top under the idea that the fossils proved it to be the newer part. (3) The granular quartz is placed at the bottom.

The order of the strata in the Report, and the equivalents, are as follows:

Taconic System of December, 1844.	*Equivalents.*
5. *a* Black slate (Bald Mt.)	I. Cambrian.
5. *b* Taconic slate.	III, I. Hudson slate and Cambrian.
4. Sparry limestone.	II. Lower Silurian.
3. Magnesian slate.	III. Hudson slates.
2. Stockbridge limestone.	II. Lower Silurian.
1. Granular quartz.	I. Cambrian.

* H. D. Rogers, this Journal. xlvii, 137, 247, 1844. The address is a discussion of geological views, and is of permanent interest. His remarks on the Taconic system occupy pages 150 to 153; and he ends them with the suggestion that the Taconic system, instead of belonging exclusively to the Champlain division, may "include also some of the sandy and slaty strata here spoken of as lying beneath the Potsdam sandstone," referring to his own observations in Virginia and East Tennessee.

The system thus had Cambrian at top and Cambrian at bottom. In the chapters on the granular quartz, doubts about its true position are admitted; but the decision as to its being the oldest in the series is not recalled.

The Report has an appendix on pages 109–112; and its closing sentences, which show wavering opinions, are important in the history. After saying that in this system of beds, made when the earth's condition earliest admitted of it, "we find the earliest beings which had life and vitality," he adds (p. 112): "We do not feel confident that it is in the earliest of these deposits that we have discovered fossils. Mr. James Hall, however, informs me that he found the *Scolithus*, a tubular polyparian, in the most easterly mass of the granular quartz. On visiting the place as described to me, I was not successful in my search for this fossil, but *at another locality I found what appears to be an orthoceratite.* The fossils, however, are more abundant in the newer rocks of this system; and they belong to beings of an extremely delicate construction, as the reader may see by reference to our description in another part of this report." The orthoceratite is not figured or again mentioned.

Prof. Emmons was led to make the "Black slate" of Bald Mountain either "a distinct rock, or merely the upper portion of the Taconic slate" by his discovery "during the early part of September," 1844, of a fossil "which resembles closely an Annelide," and the finding at the same place by Dr. Finch of two species of trilobites. The trilobites were named *Atops trilineatus* "evidently allied to *Triarthrus Beckii*, so abundant in the Utica slate" and *Elliptocephala asaphoides*, and figures are given on pages 64, 65. The "Taconic slate" of eastern New York, including the Hoosic slate, and occupying, as he says, "almost the whole of Columbia, Rensselaer and Washington Counties and reaching to St Albans," was also put with the upper fossiliferous part of the system (pp. 67 to 71), because of the discovery of Annelid markings chiefly, *Nereites* and *Myrianites.*

These new New York fossils had claims to a place in the first volume of Prof. Hall's Paleontology of New York, which was published nearly two years later, the preface bearing the date September 1, 1846. The author made the *Atops* identical with *Triarthrus Beckii* and hence referred both trilobites, together with the slates, to the Hudson river group; and the Elliptocephalus was referred to the genus *Olenus.* In the same month, the question of identity was discussed at the meeting of the Association of Geologists and Naturalists and a committee of investigation appointed for its consideration

and at the following meeting in 1847, Mr. S. S. Haldeman, the chairman of the committee, made an adverse report.* A reply from Mr. Hall appeared in this Journal in 1848.†

The discussion was continued at the first meeting of the American Association for the Advancement of Science (an expansion of the Association of American Geologists and Naturalists), in 1848, when Prof. Emmons read a paper entitled "On the identity of the *Atops trilineatus* and the *Triarthrus Beckii*, with remarks upon the *Elliptocephalus asaphoides*," in which he gives a full comparison of characters and also points out the differences between the latter species and either of the allied genera *Olenus* and *Paradoxides*.‡

The following year, 1849, a new advocate of the views of Rogers and Mather, in opposition to Emmons, appeared, in Mr. T. S. Hunt, then of the Geological Survey of Canada, who presented that year to the American Association for the Advancement of Science, at its second meeting in Cambridge, an abstract of the Geological Report of Canada for the year 1847–8.§ But it does not appear that either Mr. Hunt, or any one connected with the Canadian survey, had made the Taconic region a subject of investigation.

1855 to 1859; Phase III.—In the year 1855, Prof. Emmons made, in his new volume entitled "American Geology," his *third* presentation of the Taconic System.‖ The chief changes introduced are the following: (1) The fossiliferous portion of the system is now called the *Upper Taconic*, and the rest the *Lower Taconic*; (2) the Sparry and Stockbridge limestones are brought together as one formation; (3) the synclinal character of Greylock is first recognized and figured; and (4) extensions of the system to new localities are mentioned.

The order of succession in this third phase of the system and the true equivalents are as follows:

	Taconic System in 1855.	*Equivalents.*
Upper Taconic.	2. Black slate of Bald Mountain.	I. Cambrian.
	1. Taconic slate.	III, I. Hudson slates and Cambrian.
Lower Taconic.	3. Magnesia slate.	III. Hudson slates.
	2. Stockbridge limestone.	II. Lower Silurian.
	1. Granular quartz.	I. Cambrian.

* S. S. Haldeman, this Journal, II, v, 117, 1848. At the same meeting, in 1847, Prof. C. B. Adams, of the Vermont Geological Survey, read a brief note on the Taconic rocks of Addison County, Vt., in opposition to the system.

† James Hall, this Journal, II, v, 322, 1848.

‡ E. Emmons, Proc. Amer. Assoc. for 1848, vol. i, p. 16.

§ T. S. Hunt, Proc. Amer. Assoc. for 1849, vol. ii, p. 325, and this Journal, II, ix, 12, 1850.

‖ Occupies pages 1 to 122 of Part II of the American Geology, 8vo, Albany, 1855.

This system of 1855, like that of 1844, has a top and bottom of Cambrian rocks. The succession of rocks in the "Lower" Taconic—which, it should be remembered, were the only rocks in the system when Rogers wrote in 1841 and 1844 and Mather in 1843—coincides with the views early set forth by Rogers, and with the order established by the most recent discoveries of fossils.

Professor Emmons, on page 70 of the American Geology, earnestly sustains the *azoic* character of the "*Lower*" Taconic, and particularly that of the slates of Saddle Mountain or Greylock. But the sentences about the occurrence of fossils in other parts of the "Lower" Taconic are left ambiguous. Speaking of the Taconic system as a whole on the closing page (p. 122) he says: (3) "It is a vital system, having been deposited during the period when organisms existed." (6) It "carries us back many stages farther in time when life gave vitality to its waters than the Silurian." He also says: "(1) Its series, divided into groups, are physically unlike the Lower Silurian series." "(2) It supports unconformably at numerous places the Lower Silurian rocks." Again on page 49: This group, "the 'Lower' Taconic, is mostly anterior to the Organic period." No locality of Taconic trilobites is mentioned in the chapters except that of Bald Mountain in Rensselaer Co., N. Y., and one of much interest in Augusta Co., Virginia, which had afforded Professor Emmons the small species he named *Microdiscus quadricostatus*.

In 1854 or 1855 new Trilobites, related to those of Bald Mountain, were found in the Black Slates of West Georgia, Vermont, within the range of beds referred to the "Upper" Taconic. Passing into the hands of Mr. Zadock Thompson, who had been assistant in the Geological Survey of the State under Professor C. B. Adams, the specimens were sent to Professor Hall, and in 1859, they were figured and described by him as "Trilobites of the shales of the Hudson River Group," under the names *Olenus Thompsoni*, *O. Vermontana* and *Peltura holopyga*, and the beds were thus made equivalents of the Bald Mountain slates.* Although these fossils

*J. Hall, Twelfth Annual Rep. N. Y. State Cab. Nat. Hist., pp. 59–62, 1859. Also Vol. III, N. Y. Paleontology, 1859, p. 325; Rep. Geol. Vermont, p. 367, where the two species of Olenus are *united* under the name *Barrandia Vermontana*. In Vol. III of the Paleontology, Professor Hall says, on page 94, "In the western flank of the Green Mountain range, the great variety of schists, designated as talcous, mica, gneissoid mica, hornblende and calcareous mica slates are all results of metamorphism of Silurian strata;" and on p. 83: "It is now many years since the belt of the country was regarded as one great Primary mass. Later observers began to yield a little and contented themselves with a Primary axis; and now we have the evidence, derived from fossils occurring at intervals over much of the area between the Hudson and the Connecticut rivers, as well as

were not formally claimed as Upper Taconic by Professor Emmons, they have passed as such. His Manual of Geology, the preface of which bears the date May 1, 1859, contains a good figure of a large trilobite under the name *Paradoxides brachycephalus*,* which (as first suggested by Professor C. H. Hitchcock in 1861† and is recently recognized by Mr. Walcott)‡ is identical with Hall's *Olenus Thompsoni*; and it was evidently so named before the publication of Prof. Hall's paper, though whether *published* before is not certain. Unfortunately, Professor Emmons failed to mention the locality of his specimen. On page 87, he makes the following judicious remark: "According to Barrande, the *Paradoxides* and

from the geological structure of the country, that these rocks all consist of strata lying between the base of the Silurian and the beginning of the Coal-measures."

On page 94, in a note, occurs the statement—of historical interest and therefore here cited—that staurolite and some other minerals "mark with the same unerring certainty the geological relations of this rock [a mica schist passing through central New England] as the presence of *Pentamerus oblongus. P. galeatus, Spirifer Niagarensis, S. macropleura*, and their respectively associated fossils, do the relations of the several rocks in which they occur." It was a valuable suggestion at the time, but one that the establishment of the facts just cited from p. 83 has now set aside.

In 1857, two years before the publication of Vol. III of the N. Y. Paleontology, cited from above, Professor Hall delivered an address before the American Association at Montreal. The writer was absent and never learned anything about its contents; it was never published. In 1882, only six years since, appeared a pamphlet, of forty pages, entitled "Contributions to the Geological History of the American Continent. The Address of the retiring President delivered before the first Montreal Meeting of the American Association for the Advancement of Science, August, 1857, by JAMES HALL." A note to the title is appended in which the author says: "The original manuscript of his Address" "has been copied without any supervision by him or any changes suggested by him." This publication of the Address cannot claim to have historical value and hence demands no notice here; for it came out *twenty-five years after date.* It has no scientific importance; for the subjects presented are much more fully and more satisfactorily discussed in the 96 quarto pages of the valuable Introduction to Vol. III, above mentioned, all of which is Professor Hall's, and besides is two years later than the Address. In the Appendix to this pamphlet on p. 68, it is stated that "the Address has been facetiously criticised as proposing a system of mountain-making with the [origin of the] mountains left out" Accordingly, the *Address*, although it had never been published, had on one subject been "facetiously criticised." The critical remark referred to occurred in volume xlii (1866, p. 210) of this Journal, in a note on views published by Professor Hall *in his Volume III*, as is stated in the note, and had no reference to the unpublished and wholly unknown Address. Some officious friend has made a slip here: Professor Hall could not have so forgotten himself. The pamphlet closes, following this, with two pages of "Notes on Professor James Hall's Address by T. Sterry Hunt."

* Manual of Geology by E. Emmons, 290 pp. 8vo. Philadelphia, 1860; see p. 88. Also C. D. Walcott on Cambrian Faunas, 2d paper, Bull. No. 30, U. S. G. S., 1886. p. 167. The name *Paradoxides asaphoides* is given by Professor Emmons for the figure on page 87, as if his first intention was to have inserted his old figure of *Elliptocephalus asaphoides*, but afterward decided to insert a figure of the new species. The name *P. brachycephalus* is changed to *P. macrocephalus* in a second issue of the Manual (1860), both under the cut on page 88 and in a note to page 280, and the corrected name is cited by Mr. Walcott.

† Rep. Geol. Vermont, p. 367.

‡ Bull. U. S. G. S., No. 30.

Olenus belong to his Primordial zone or are Sub-silurian in Bohemia. In this respect our Paradoxides are also Sub-silurian: and hence it has been shown that the Primordial zone in Bohemia is in coördination with the upper series of the Taconic rocks." Professor Emmons's letters to Mr. Marcou written in 1860 and published by the latter in the Proceedings of the American Academy for 1884, show that he meant here to emphasize "Upper" Primordial; for he protests that only a small part of his system is coincident with Barrande's Primordial.

1860 to 1863.—The years 1860 to 1863 were epochal in Taconic History. Great light was let in upon the system by letters of August, 1860, from Barrande, the eminent paleontologist of the Silurian of Bohemia, addressed to Professor Bronn of Heidelberg and Mr. Marcou of Cambridge, Mass., and also from a memoir read by him before the Geological Society of France. Having before him the figures and descriptions of the Georgia trilobites, referred to above, received from Mr. Billings, he pronounced them unquestionably Primordial, thus confirming the decision of Professor Emmons just mentioned.

But Barrande, adopting in his Memoir in full the views of Emmons on the Taconic system, and regarding the Primordial fossils as really characteristic of a great Taconic system of rocks extending far below the Olenus or Paradoxides zone, speaks of the Taconic as the American Primordial—his own system under unusual development—a view not satisfactory to Professor Emmons, for he had in contemplation for his Lower Taconic much greater depths, something like the unsounded Huronian, equivalency with which he thought he could make out.* And thus confusion was introduced by Barrande along with the

* Barrande's letters are addressed—Paris, July 16, 1860, to Professor Bronn of Heidelberg, and August 14th, 1860, to M. J. Marcou. They were read before the Boston Soc. Nat. Hist. in October, 1860, and are published in the Proceedings, vol. vii, 371; also in this Journal, II, xxxi, 210, 1861, with an omission of Mr. Marcou's name because of its unmentioned omission on the part of the sender (from Canada) of the communication; also in the Geol. Rep. Vermont (with the same omission) p. 377; and also, with other letters, in Mr. Marcou's paper in the Proc. Amer. Acad., vol. xii; see page 411. In this Journal and in the Vermont Report the letters are followed by letters to M. Barrande from Logan and from Hall; also in the Boston Proceedings, vol. vii, and also vol. viii, 239, by remarks of Mr. Marcou, giving his view of the bearings of the facts on the Taconic system of Emmons, with some additional facts. Barrande's Memoir referred to above is entitled, "Documents anciens et nouveaux sur la Fauna primordiale et le Système Taconique en Amérique," and was presented to the Geological Society of France, Nov., 1860, and Feb., 1861.

Barrande's letters appeared also in the Canada Nat. and Geol. for 1861. The facts show that some person connected with the Geological Survey of Canada is accountable for the "omission" above referred to. Mr. Marcou's paper of 1884 gave the editors of this Journal their first knowledge of it.

light. It would not have been so, we are sure from his careful Bohemian work, had he been within reach of the stratigraphical problem, for he would have withheld his general conclusion until he had investigated the region of the Taconic rocks.

Trouble came in 1860 again through the recognition by Logan of the Quebec Group in Canada—based on fossils from the vicinity of Quebec that corresponded in age apparently to the combined Calciferous and Chazy Groups.* For this step was followed by Logan's announcing, without previously making a careful stratigraphical study of the region, that the Taconic slates and limestone were, for the most part at least, of the Quebec Group.

Light came in again through the Vermont Geological Survey;† (1) by the discovery of fossils of undoubted Silurian age at several localities in the Stockbridge (Eolian) limestone of Vermont, the Report says (p. 421) Silurian, Devonian, and possibly Carboniferous); (2) by the exhibition of the topographical relations of the rocks on the colored geological map of Vermont; and (3) through the stratigraphical sections across the limestone and slates, making in Mt. Anthony, Mt. Equinox, Spruce Peak, Mt. Eolus or Dorset and Danby Mountain the slates to lie in synclines with the limestone underneath, precisely as had been proved for Greylock by Emmons. Here at one stroke, Emmons was sustained in his stratigraphy as regards his "Lower" Taconic, and shown to be probably wrong in his conclusion as to the pre-Potsdam age of the limestone, and part at least of the slates. No definite conclusion was reached by the survey as to the age of the quartzyte, opinion varying between Potsdam and Medina.‡

* Sir Wm. Logan, Remarks on the Fauna of the Quebec Group of Rocks and the Primordial Zone of Canada, Jan., 1861, Letter to Barrande, this Journal, II, xxxi, 216, 1861; Considerations relating to the Quebec Group, Can. Nat. and Geol., p. 199, May, 1861.

Mr. Billings first observed the peculiar features of the fossils of the so-called Quebec Group in May, 1860 (Geol. Rep. Can., 1863, p. viii), and the Canadian Nat. and Geol. for 1860 contains his earliest descriptions of the fossils, afterward given in full, with an account of the rocks by Logan in the Can. Geol. Rep. for 1863, and more completely in Billings's Palæozoic fossils, vol. 1.

† Rep. Geol. Vermont by E. Hitchcock, E. Hitchcock, Jr., A. D. Hager and C H. Hitchcock, 1861. In a note published in the Proceedings of the Boston N. H. Soc., vol. xxiv, 1888, Prof. C. H. Hitchcock states that the printing of the Report commenced in 1861, and was all completed that year, excepting the Appendix on "Lower Silurian fossils" by E. Billings.

‡ Ibid., pp. 356, 500. On the latter page, the opinion is cited from Professor Hall, based on the discovery of a species of Lingula, that the quartzyte is "of the age of the Clinton Group or of the Medina Group," Upper Silurian formations. Bearing on the history we find in the Proc. Boston Soc. N. H., vii, 237, 1860, a note by Professor W. B. Rogers, in which, in view of the reference to the Medina group, he cites approvingly, from a manuscript paper of his written in 1851, paragraphs sustaining the Medina age of the Vermont Quartzyte and Red Sandrock. The latter rock Emmons never included in the Taconic.

But along with the light from Vermont, doubts entered through the reference of some of the fossils of the limestone to the Upper Silurian and perhaps Devonian, and the use made of the few fossils of the Quartzyte. The facts were partly righted in 1862 by Mr. Billings, the paleontologist of Canada, who reviewed the Vermont Report in this Journal, and claimed that "the evidence of the fossils furnishes no reasonable ground for placing the formation above the Lower Silurian."*

Accepting the stratigraphical sections in the Vermont Report as teaching what they appear to teach, and recognizing the Lower Silurian age of the fossils from the limestone, and accepting also Barrande's confirmation of Emmons's decision as to the Primordial relations of the "Black slate" trilobites, the general bearing of the facts made known, during this epoch of progress and drawbacks, could hardly be mistaken.

At this time the first edition of the writer's Manual of Geology † was published. The preface bears the date of the close of the printing, November 1, 1862. The Potsdam period in American Geology had already become expanded into the Primordial by the discovery, six years before, near Boston, of specimens of *Paradoxides Harlani* ‡ and by facts received from abroad; and it is designated in the work (pp. 169, 171) the "POTSDAM OR PRIMORDIAL PERIOD," and made the equivalent of the era of the Paradoxides and other Primordial beds of Scandinavia and Bohemia, as well as of that of the Lingula Flags and underlying Cambrian of Great Britain. Moreover, *Paradoxides*, *Olenus*, and other Lower Cambrian genera are cited, and *P. Harlani* appears among the figured species. Barrande's determinations of the Georgia Slate Trilobites, making them and the beds containing them Primordial, are recognized by mentioning the beds and fossils among the facts of the "Potsdam or Primordial Period"—conforming in this to the decision of Emmons as well as Barrande.

The Vermont discoveries of fossils in the Eolian limestone had proved that the limestone and the overlying slates were

* E. Billings, this J., II., xxxiii, 416, 1862.

In 1870 the chief divisions in the geology of Vermont were briefly stated by Prof. C. H. Hitchcock in a folio of six pages bearing the date of March 1st. His further study of the State, in connection with the work of the Canadian Survey, had led him to refer at this time the Eolian or Stockbridge limestone and associated slates to the Quebec group, and the Quartzyte, Red Sandrock and the Georgia slates and Black slate to the Potsdam or Primordial, the last-mentioned the oldest.

† Manual of Geology by James D. Dana, 798 pp. 8vo, illustrated by a chart of the world and over 2000 figures. Philadelphia, 1863.

‡ W. B. Rogers, this J., II, xxii, 296, 1856, from a letter to J. D. Dana of August 13. Prof. Rogers compares the fossil with the *P. spinosus* of Barrande, and identifies it with the *P. Harlani* of Green. Mr. Green's cast of a specimen of unknown locality, had been widely distributed, and had reached Barrande. He also shows by Green's description of the rock, that his specimen was probably of the same locality.

later rocks than the Primordial, at least as late as Lower Silurian; and hence the term Taconic could not have been substituted for Primordial, as only a small part of the system was Primordial: the name belonged by first right to the original Taconic of 1842. The Primordial addition to the top of the Taconic column made by Emmons in 1844 was rectified by simply recording the facts in their proper places. The Eolian or Stockbridge limestone and other "Lower" Taconic rocks are mentioned in the Manual under the Calciferous (pp. 175, 176) in connection with remarks on the Quebec group; but it is added that "fossils probably of the Trenton period occur in the Vermont limestone"; and on p. 391, evidence in favor of a Trenton rather than a Calciferous or Quebec age is presented, based on the facts from the Vermont Geological Survey and the remarks by Billings.

By the close of the year 1862, therefore, the Black slates of the "Upper" Taconic had reached their right place in a Geological Manual. There remained however to be yet made out their particular horizon in the Cambrian, the particular periods of the Lower Silurian represented in the Stockbridge limestone, and the age of the quartzyte.

1865 to 1872.—In May, 1870, Rev. A. Wing, of Vermont, collected fossils from the limestone at West Rutland "not 100 yards from an abandoned marble quarry," which were sent a year later (June, 1871), to Mr. E. Billings, of Montreal, who reported upon them in this Journal for 1872, pronouncing them probably Chazy.* Mr. Wing had been exploring since 1865, in order to "ascertain if possible the geological age of the limestones, slates and quartzite," and relied on Mr. Billings for the determination of his fossils.† In 1867, Mr. Billings identified for him *Asaphus canalis*, two or three species of *Bathyurus*, *Maclurea matutina*, from the limestone in Cornwall, Vt., and made the species *Calciferous*. The same year he found the Trenton fossil *Trinucleus concentricus* in place "in great abundance" in Sudbury; also about this time or between it and 1872, he found "*Bathyurus Saffordi*, a Quebec Group trilobite" in East Cornwall; *Bathyurus extans*, a Birdseye species, *Columnaria alveolata*, a Black River species, and the *Trinucleus*, east of Shoreham; and confirmatory species as to the Calciferous as well as the later periods from other localities.

By 1872,‡ Mr. Wing had established one of the points he had in view, that the limestone was not, as Logan had held, of the Quebec group, or of Calciferous and Chazy only, but embraced the Trenton also, and apparently all the Lower Silurian forma-

* E. Billings, this J., III, iv, 133, 1872.

† A. Wing, this J., II, xiii, 332, 405, 1877.

‡ This J., III, iv, 1872; and for his conclusions, p. 414.

tions from the Calciferous to the Trenton; and, consequently, he had made it certain that whatever slates were really overlying were of Utica or Hudson age.

In 1869, an article by Prof. J. B. Perry appeared in this Journal, sustaining, by the results of his observations in Vermont, the Taconic system as presented by Emmons. As its principal stratigraphic points have now been disproved by the discovery of fossils, and evidence of the existence of faults and flexures which he misunderstood, it need not be noticed here.

1872 to 1886.—In 1871 the writer entered the field, believing that the Chazy fossils of West Rutland—the only part of Wing's discoveries then published—and the earlier discoveries of the Vermont Survey, made the region a good and certain base for a determination of the age of the Massachusetts and more southern portions of the Taconic rocks, as well as of the Vermont portion, and, thence, of the age of the schists throughout the Taconic Range. My purpose was (1) to prove the continuity from north to south of the three *associated* Taconic formations, the quartzyte, the limestone and the slates or schists; also (2) to work out the system of flexures; (3) to ascertain whether the Taconic Mountains were generally or not of synclinal structure, as they were made by Rogers, Mather and Hall, and in 1864 by Logan;* (4) to settle the question as to continuity from east to west of the limestone of the different north-and-south belts; (5) to apply the evidence from fossils, making them the sole basis for fixing the age of the beds; and finally (6), to use the evidence of the age, thus obtained, for the determination of the age of the hydromica schists, chloritic schists, garnetiferous and staurolitic schists, and other rocks of the Taconic Mountains, and thus test the value of, or give greater precision to, the assumed "lithological canon" first propounded by Prof. Emmons (p. 414). My work was continued in Western New England and Eastern New York at intervals from 1871 to the close of the season of 1886. In 1876 I accompanied Mr. Wing on a Vermont excursion, visiting besides other places, the West Rutland region of fossils in the limestone; a locality of small Orthocerata, apparently Calciferous, in the limestone two miles north of Middlebury, which Mr. Wing figured;† and the region of the Snake Mountain overthrust fault which he well understood.‡

By 1878, the problem began to receive new light from the discoveries of fossils outside of Vermont. In 1878, Mr. T. N. Dale announced Brachiopods of the Hudson Group in the Poughkeepsie Taconic slate.§ In 1878, Professor Wm. B. Dwight

* This J., II, xxxix, 96, 1865.

† A. Wing, this J., III, xiii, 406, 1877, where the Orthocerata are figured.

‡ Ibid., p. 413.

§ Dale, this J., III, xvii, 57, 1879.

began his numerous discoveries of Trenton and Calciferous fossils in the belts of "Sparry limestone" of Dutchess Co., N. Y., which he has continued to 1888;* and in 1885 and 1886 made other discoveries in the "Sparry limestone"—strictly the southern part of the Eolian—in Canaan, Columbia Co., N. Y., just west of the Taconic Range.† Thus the evidence of the Lower Silurian age of the limestone and slate went on accumulating. Further, both Hudson River and pre-Potsdam Cambrian fossils were reported by Mr. S. W. Ford from the east border of the Hudson near Schodack landing,‡ and Upper Cambrian by Professor Dwight near Poughkeepsie,§ both being cases of the uplift of Cambrian beds along a fault. Professor Dwight found the Hudson shales to be the prevailing rock in Dutchess County; also that it was intersected by numerous faults: Potsdam occurring faulted against Trenton, against Calciferous and against Hudson shales; and the Calciferous against Trenton and Hudson shales. Again, in 1886, Mr. I. P. Bishop, of Chatham, Columbia Co., N. Y., eight miles southwest of Canaan, announced‖ the occurrence of Hudson group graptolitic schists and fossiliferous Trenton limestone at that place, and the continuation of the beds northward to the borders of Rensselaer Co., N. Y., and south to Ghent—facts that bore on the age of the "Taconic slate" of Emmons not only for Columbia County but also for the region north.

My papers appeared in this Journal in 1872, 1873, 1877, 1879, 1880, 1884, and finally in 1885 and 1886, the series was continued, with new results, and the completion of a geological map of the limestone areas of the Taconic region east and west of the Taconic Range from Northern Bennington in Vermont to the southern limit of Canaan and Salisbury, Conn. It is not necessary to mention here conclusions. I was slow in reaching any positive conclusion about the age of the quartzyte because of the non-discovery of fossils, which I made the only reliable evidence of age. But in 1884 discovering chondroditic limestone in eastern Berkshire as evidence of the presence of Archæan, I made out an eastern quartzyte as Potsdam or Cambrian, leaving the quartzyte that alternates with the schists and limestone in the center of the Taconic limestone region, still in doubt. But the evidence was not sufficient to prove that there was a continuous belt of Archæan along eastern Berkshire and the Green Mountain Range to the north, so that

* W. B. Dwight, this J., III, xvii, 389, 1879, xix, 50, 451, 1880, xxi, 78, 1881, xxvii, 249, 1884.

† W. B. Dwight, this J., xxxi, 248, 1886.

‡ S. W. Ford, this J., III, xxviii, 35, 206, 242, 1884, xxix, 16, 1885.

§ W. B. Dwight, this J., III, xxxi, 125, 1886, xxxiv, 27, 1887.

‖ I. P. Bishop, this J., xxxii, 438, 1886.

part of the mica schist and gneiss remained in doubt, as, for example, that of Hoosic Mountain east of North Adams, and that of Mt. Mansfield in the Green Mountains,* not knowing whether to pronounce them of the age of the Taconic Greylock schists which they closely resemble, or of that of the schists in the Quartzyte formation, or of Archæan age—thinking the last the least probable.†

In 1884 Professor C. H. Hitchcock published an account of new sections made by him across Vermont and New Hampshire, sustaining essentially his former conclusions as to the Lower Silurian age of the limestone and slates, making the Eolian limestone Lower Silurian.‡

Other papers, besides those that have been mentioned, appeared during the thirty years from 1855 to 1886, but none of importance that were the direct result of investigation of the Taconic region apart from what appeared on Northern Vermont and Canada. Articles on the Taconic system by Dr. T. Sterry Hunt have come out from time to time since his first in 1849 giving the views he had adopted ; views that were strongly opposed to Professor Emmons for nearly thirty years, and for the last ten, from 1878 to 1888, as strongly or a little more so, in favor of the Taconic system and in contest with the facts that were fast accumulating against it. As the arguments and conclusions presented were at no time based on his own investigations in the Taconic region there has been no occasion to cite from his papers.

1887, *1888*.—In 1886 Mr. Charles D. Walcott, the excellent paleontologist of the United States Geological Survey, commenced the study of the Taconic slates, limestone and quartzyte of Northern and Southern Vermont and the adjoining counties in New York ; and in 1887, he continued his work southward into Williamstown in Massachusetts and to Berlin, southwest of Williamstown, in eastern New York. He added largely to the number of known Cambrian fossils of the Georgia region in Vermont and of Washington County in New York besides studying the stratigraphy ; made many new discoveries of fossils in southern Vermont, finding in the

* Mt. Mansfield is the only peak of the Green Mountains which I have ascended.

† The quartzyte regions of (1) Washington, Mass., southeastern Pittsfield and eastern Lenox, (2) the eastern border of Tyringham, Mass., (3) the southern border of Canaan, Ct., adjoining Cornwall, and (4) the northern border of high eastern Sharon, Ct., near Salisbury, where there are quarries, are among the best localities for the study of transitions in the quartzyte toward gneiss ; they were to have been my field of work in 1887, and failed to be so because of my sudden move to the Hawaiian Islands.

‡ C. H. Hitchcock, 34 pp. 8vo, with 2 plates, Concord, N. H., 1884. Bull. Amer. Mus. N. Hist., i, no. 5, p. 155, 1884 ; a note to the title says, "This article was prepared in 1882."

Stockbridge (Eolian) limestone Trenton fossils within half a mile of the Massachusetts line in Pownal; other Lower Silurian fossils on both sides of Mt. Anthony, three miles south of Bennington, a Trenton crinoid included; Trenton fossils in Williamstown, at the Hopper, at the west foot of Greylock and others in Berlin south of South Berlin; and at Hoosic Falls in Rensselaer Co., New York, west of Bennington, Trenton fossils again.*—The results warrant full confidence, he says, in the Calciferous-Trenton age of the limestone. Further, in the slates at Hoosic he obtained Graptolites, as had long before been found, of Hudson age. In the study of the quartzyte of Vermont, specimens in the Amherst cabinet (Amherst, Mass.) afforded him the species *Nothozoe Vermontana*, *Olenellus Thompsoni* and *Hyolithes communis;* the quartzyte mountain, two miles east of Bennington, Vt., gave him specimens of *Nothozoe*, *Olenellus* and *Hyolithes*, and the quartzyte of the west summit of Clarksburg Mountain or Oak Hill, on the borders of Williamstown, an *Olenellus*. These discoveries were preceded in 1886 by finding, along with Professor Dwight, *Hyolithellus micans* in the limestone resting on the quartzyte of Stissing Mountain in Dutchess Co., N. Y. (the quartzyte referred to by Professor Emmons), and heads of *Olenellus Thompsoni* at the same place in the quartzyte itself.

The colored map accompanying his paper in volume xxxv (1888) of this Journal has the above mentioned localities of fossils indicated, and also those of Cambrian age within the area of the Taconic slates over eastern New York and the borders of Vermont. The fossils are positive evidence of the age of the slates at the localities where they occur. But how far the slates away from the localities are Cambrian, or how far they are, instead, of the Hudson group, with faults here and there bringing up Cambrian, in Eastern New York, as in Dutchess County, remains yet to be ascertained. The doubt does not affect the general conclusion from the facts. Further, Mr. Walcott made out that the quartzyte formation, and the Bald Mountain and Georgia slates were alike in belonging distinctively to the Olenellus section of the Cambrian.

These discoveries of Mr. Walcott afford the first demonstration of the age of the quartzyte, and give new precision to our knowledge of the age of the Georgia, Bald Mountain and associated slates. Besides this, they give full completeness to the proof, that had been for years accumulating, of the Lower Silurian age of the Taconic limestone. They show, moreover, that the Primordial beds constituting Emmons's "Upper" Taconic, on account of which the terms Primordial and Taconic have by some been thought to be rightful synonyms, are

* C. D. Walcott, this Journal, III, xxxiv, 187, 1887, xxxv, 229, 307, 394, 1888.

only outcrops of the Cambrian formation of the "Lower" Taconic; that the "Lower" Taconic includes the "Upper" and is therefore all there is of Taconic.

It is thus finally made positive that the Taconic system is not a pre-Silurian system, and that the claiming for its equivalency with the Huronian was but a leap in the dark. It is manifest, in fact, that "Taconic system" is only a synonym of the older term "Lower Silurian," as this term was used by geologists generally, twenty, thirty and forty years since, and by many writers till a much later date.

It is almost fifty years since the Taconic system made its abrupt entrance into geological science. Notwithstanding some good points, it has been, through its greater errors, long a hindrance to progress here and abroad. It has also been a promoter of investigations of wide bearing and influence. But, whether the evil or the good has predominated, we may now hope, while heartily honoring Professor Emmons for his earnest geological labors and his discoveries, that Taconic ideas may be allowed to be and remain part of the past.

1841-1888.

ART. XLIII.—*Certain Generic Electrical Relations of the Alloys of Platinum*;* by C. BARUS.

IF the specific electrical resistance (s) of a metal be expressed by $s=f(\chi, t)$, where t is the symbol of temperature and χ a variable parameter, then the data of the present paper may be said to furnish evidence of an inherent physical relation between $f(\chi,0)$ and $f'(\chi,0)$—i. e. the zero values of s and its first derived function with respect to t,—provided the largest admissible value of χ be small in comparison with its maximum value. Usually variations of χ are produced by changing the qualities of the originally pure metal by small quantities of some foreign ingredient, metallic or not. With the understanding thus laid down, $f'(\chi,0)/f(\chi,0)$ is the succinct interpretation of what is ordinarily called temperature-coefficient, and which in the present paper will often be denoted by α. Conformably with the notation indicated $f(0,0)$ and $f'(0,0)$ are the constants of the unalloyed metal. When this is not thus explicitly stated, I will for the sake of brevity use $f(0)$ and $f'(0)$ in place of $f(\chi,0)$ and $f'(\chi,0)$, respectively.

* This paper indicates the chief result of the third chapter of the Bulletin on the measurement of high temperatures, to which reference has already been made. (See this Journal, xxxv, p. 407, 1888.)

The expression for electrical conductivity is here $1/f(\chi, t)$, to be abbreviated λ. If $s=s_0(1+\alpha t+\beta t^2+\ldots)$, it follows that $\lambda=\lambda_0(1-\alpha t+(\alpha^2-\beta)t^2-\ldots)$; and hence the temperature coefficients, taken in the sense just defined, are numerically identical, no matter whether reference is made to s or to λ.

The alloys of which the present paper treats are all characterized by high melting points, and by *non-crystalline* structure. Alloys fusing below red heat have not been systematically investigated, or lead to involved results. The case of amalgams* is complicated by changes of the physical state of aggregation. Strictly speaking investigations like the present hold only for those alloys for which data are in hand. Cf. § 3.

2. The advantages of selecting platinum-alloys for the investigation in question are manifold. Melted platinum appears to be a universal solvent of metals, and hence the variety of bimetallic platinum alloys, easily producible, is very great. Again one of the remarkable electrical properties of platinum is the tendency to form alloys of phenomenally high specific resistance; and quite within the limits stated in §1, an electrical effect of alloying amounting to as much as 500 per cent of the specific resistance of platinum, is no unusual occurrence. Finally platinum alloys have not yet been systematically studied. The present contribution is therefore new.

In the case of steel to which I shall allude in passing, variations of resistance allied in character to those here discussed may be produced by changes of temper. The range of electrical variation here is also very large, amounting to more than 300 per cent of the resistance of soft steel.

Phenomena extending over such an enormous range, and which admit of exact measurement throughout the whole interval of variation, deserve most careful scrutiny and comparison even in their approximate relations. But there is further evidence in hand of the importance of which, when my work was in progress, I was quite unaware. I shall endeavor to digest it in the next paragraph.

3. A research into the relations of electrical conductivity and temperature makes up a part of the labors of Matthiessen. In addition to his well-known results for pure metals, Matthiessen† and his friends investigate the electrics of alloys of PbAg, SnAu, SnCu, SnAg, ZnCu, AuCu, AuAg, PtAg, PdAg, CuAg, FeAu, FeCu, PCu, AsCu, and some other metals. Unfortunately not all of these alloys are available for the present discussion, as Matthiessen's purpose seems rather to have been the exploitation of a great number of series of groups of alloys. On the other hand it is my purpose to examine the

*Cf. C. L. Weber: Wied. Ann., xxiii, p. 447, 1884; ibid., xxxi, p. 243, 1887. Battelli: Beiblätter, xii, p. 587, 1888.

† Matthiessen and Vogt: Pogg. Ann., cxxii, p. 19, 1864.

electrical behavior of as many alloys as possible of one given group. On perusing Matthiessen and Vogt's results, it appears that lead alloys,* tin alloys and iron alloys will have to be excluded from the present consideration, inasmuch as the data are either insufficient in number, or lie too far apart from each other and from the extremes of this series, or because of mechanical difficulties encountered in making the alloys and shaping the wires. There remain a very full series of copper alloys, viz: CuSn, CuZn, CuFe, CuP, CuAs; a series of silver alloys, viz: AgAu, AgPt, AgPd, AgCu; and a few gold alloys, viz: AuCu, AuAg. In view of the importance of these data I have computed the following tabular statement of Matthiessen's results, re-arranging the data in a way which for my special purposes is expedient. I have also added Matthiessen's† results for pure, soft metals. In table I, λ'_0 denotes the conductivity in Matthiessen's standards ($Ag=100$), a the temperature coefficient of the alloy, of which the composition is given on the same horizontal row. I have rounded off Matthiessen's long numbers, because the arbitrary errors introduced during the mechanical preparation of the alloys, together with the errors of structure and hardness and the more serious errors of imperfect homogeneity, make the extreme accuracy of the electrical datum illusory. The table furthermore contains λ_0, the electrical conductivity in microhms referred to the cubic centimeter. This reduction is made by means of mercury.‡ In the last two columns of table I, the value of a computed by the formula $a+m=n\lambda_0$ and the corresponding errors are inserted. Of these results further mention will be made below, and I need here only state that the constants m and n given at the end of the table are those which I derived from all the relevant observations, by the method of least squares.

The compositions given are volume per cents, except in the cases of phosphides and arsenides of copper where mass per cents are meant.

In interpreting these results by graphic methods, it is necessary to proceed with caution, for inasmuch as specific resistance enters into them reciprocally, large values of resistance will only be inadequately represented. Neverthless, although the tables contain many such values, enough data remain to exhibit the striking linear character of the curves on which the gold, silver and copper points respectively lie. The initial tangent

* The metallic ingredient present in larger amount may be fitly used in designating the alloy.

† Matthiessen and v. Bose: Pogg. Ann., cxv, p. 353, 1862.

‡ Jenkin who made similar reductions in the case of pure metals by means of lead, arrives at somewhat different numbers. A perfectly satisfactory absolute table can not be deduced.

TABLE I.—*Showing Matthiessen and Vogt's results for the electrics of gold, silver, and copper alloys.*

	Alloy.	Composition.	λ'_0.	Observed $a \times 10^3$.	$\lambda_0 \times 10^3$ microhms.	Calculated $\delta a \times 10^3$.	$\delta a \times 10^5$.
Gold alloys.	Au	----	79	3·67	506	3·69	− 2
	AuCu	1·6 % Cu	56·1	2·65	359	2·63	+ 2
	AuCu	18·3 % Cu	16·1	0·75	103	0·79	− 4
	AuAg	20·1 % Ag	21·5	1·11	137	1·03	+ 8
	AuAg	47·9 % Ag	15·2	0·70	96	0·74	− 4
Silver alloys.	Ag	----	109	3·82	691	3·83	± 0
	*AgCu	1·5 % Cu	79·7	4·12 (?)	510	----	----
	AgCu	8·2 % Cu	80·3	2·75	514	2·88	−13
	AgCu	46·7 % Cu	74·9	2·80	480	2·69	+11
	AgPt	2·5 % Pt	31·6	1·24	202	1·20	+ 4
	AgPt	5·0 % Pt	18·0	0·77	115	0·73	+ 4
	AgPt	19·7 % Pt	6·7	0·33	43	0·34	− 1
	AgPd	23·3 % Pd	8·5	0·32	55	0·41	− 9
	AgAu	19·9 % Au	21·7	0·90	139	0·86	+ 4
Copper alloys.	Cu	----	102	3·87	653	3·98	−11
	CuAg	1·6 % Ag	89·5	3·45	573	3·54	− 9
	CuAg	4·8 % Ag	82·3	3·25	527	3·29	− 4
	CuAg	22·4 % Ag	69·8	3·03	447	2·85	+18
	CuAu	0·7 % Au	84·0	3·32	538	3·35	− 3
	CuAu	19·2 % Au	20·5	0·86	131	1·11	−25
	CuFe	0·5 % Fa	38·9	1·55	249	1·76	−21
	CuZn	5·0 % Fe	60·4	2·47	387	2·52	− 5
	CuZn	10·9 % Zn	46·9	2·05	300	2·04	+ 1
	CuZn	23·6 % Zn	21·3	1·88	136	1·14	+74
	CuZn	29·4 % Zn	21·7	1·27	139	1·15	+12
	CuZn	42·1 % Zn	21·8	1·37	140	1·16	+21
	CuSn	1·4 % Sn	62·5	2·68	400	2·59	+ 9
	CuSn	6·0 % Sn	19·7	1·00	126	1·08	− 8
	CuSn	11·6 % Sn	12·1	0·69	77	0·81	−12
	CuSn	12·3 % Sn	10·2	0·67	65	0·74	− 7
	CuSn	14·9 % Sn	8·8	0·55	56	0·69	−14
	CuP	1·0 % P	23·6	1·32	151	1·22	+10
	CuP	2·5 % P	7·3	0·48	47	0·64	−16
	CuAs	trace	61·1	2·64	391	2·54	+10
	CuAs	2·8 % As	12·9	0·74	82	0·84	−10
	CuAs	5·4 % As	6·3	0·52	40	0·61	− 9

* Rejected.

$$(a+m=n\lambda_0)$$

Gold alloys	$m = -0{\cdot}000045 \pm 0{\cdot}000030$
	$n = +0{\cdot}00721 \pm 0{\cdot}00010$
Silver alloys	$m = -0{\cdot}000112 \pm 0{\cdot}000031$
	$n = 0{\cdot}00538 \pm 0{\cdot}00085$
Copper alloys	$m = -0{\cdot}000386 \pm 0{\cdot}000040$
	$n = 0{\cdot}000551 \pm 0{\cdot}00012$

concides with the initial curves throughout an enormous extent of their course. Matthiessen* who expressed a similar

* Matthiessen and Vogt: Phil. Mag. (IV), xxvii, p. 467, 1863; Pogg. Ann., cxxii, p. 19, 1864.

result under a somewhat involved form, was well justified in computing by means of it the conductivity of a pure metal from data found for metals slightly impure. This computation premises the truth of Matthiessen's other principle that with certain distinct exceptions, the electrical temperature cofficients of all pure metals are the same (cf. § 6).

4. After Matthiessen and Vogt the curious relation in question seems to have failed to enlist further attention, and I believe that the next systematic investigation is that made by Dr. V. Strouhal and myself in studying the electrics of the iron-carburets.* We did not, however, in the former paper reduce our results from the curvilinear form in which they appear when temperature coefficient is expressed in terms of resistance, to the curves of the present linear character; and hence I may expediently make this reduction here. If temperature coefficient (y) be expressed as a function of specific resistance (x), and if a curve be passed through all the points investigated for iron, steel, cast-iron, then the following principal coördinates obtain:

$$\begin{array}{llll} x= & 15 & 45 & 70 \\ y= & 0{\cdot}00420 & 0{\cdot}00166 & 0{\cdot}00130 \end{array}$$

Interpreted by an hyperbolic equation of the form $(x+l)\,(y+m)=n$, these data lead to constants

$$l=-3{\cdot}73, \qquad m=-0{\cdot}000706, \qquad n=0{\cdot}0394,$$

which do not reproduce the graphic curve satisfactorily. Neither is l by any means negligible, so that the reduction to linear forms is out of the question. At first sight this seems to prove that iron, steel and cast iron do not here form a unique series; that the resistance variation due to the change of carburation from iron to cast-iron is in its nature different from the resistance variation observed on passing from soft to hard steel. It appears below, however, that the favorable position of iron here unduly influences the result. I will temporarily withdraw both iron and cast-iron from the series. For steel alone we found (using the graphic method already referred to)

$$\begin{array}{llll} x= & 15{\cdot}9 & 28{\cdot}9 & 45{\cdot}7 \\ y= & 0{\cdot}00423 & 0{\cdot}00244 & 0{\cdot}00161, \end{array}$$

which data interpreted by the equation $(x+l)\,(y+m)=n$ now lead to the constants

$$l=0{\cdot}78, \qquad m=-0{\cdot}0001435, \qquad n=0{\cdot}0682.$$

Here the constant l is small, being only about five per cent of the smallest steel value of x admitted. Inasmuch as a result

* Cf. Wied. Ann., xx, p. 525, 1883; Bulletin U. S. G. S., No. 14, p. 15 to 25, 1885.

similarly favorable to the reduction to linear forms is obtained by adding cast-iron to the steel series, I have assumed the equation

$$x(y+m)=n.$$

Using this equation as a basis for the application of the method of least squares, the observations of Dr. Strouhal and myself lead to the results contained in the following table. These results are easily understood, and I need hardly add that according to § 1, the conductivity and temperature-coefficient of steel are respectively

$$\frac{1}{f(0)} \text{ and } \frac{f'(0)}{f(0)}.$$

TABLE II.—*Showing Strouhal and Barus' results for the electrics of iron-carburets,* $f(0)\,(f'(0)/f(0)+m)=n$.

Metal.	Temper.	$f(0)$.	$f'(0)/f(0)$. Observed.	$f'(0)/f(0)$. Computed.	Diff.
Steel	Soft	15·9	0·00423	0·00417	+ 6
"	Annealed light blue	18·4	360	366	− 6
"	" full blue	20·5	330	333	− 3
"	" yellow	26·3	280	269	+11
"	" light yellow	28·9	244	249	− 5
"	Glasshard	45·7	161	173	−12
Cast iron	--------	78·5	129	119	+10

$$m=-0·000438\pm0·000097$$
$$n=+0·05930\pm0·00151$$

Applied to steel alone, the constants computed by the method of least squares show even better agreement, viz:

$$m=-0·000303\pm0·000079$$
$$n=+0·0620\pm0·0017$$

I omit the details, with the mere remark that the difficulties of measurement with a molecularly unstable brittle body like hard steel are great.*

5. I desire now to add to these remarkable results the new data which I found for platinum alloys. I shall endeavor to make my series more nearly complete; to investigate points more nearly contiguous and nearer in position to the pure metal than was the case in the foregoing series, as well as to introduce a great variety of platinum alloys. For both in Matthiessen and Vogt's results, and in Dr. Strouhal's and my results, the position of the individual points is not always near

* Prof. J. H. Langley kindly called my attention to recent data for manganese steel. Looking up Fleming's work (Lum. electr., xxvii, p. 589, 1888), I found his results to be $s=68$ and $a=0·0012$. In the above diagram $s=68$ corresponds to $a=0·0013$, showing satisfactory accordance with experiment even in this region of abnormally high specific resistance.

enough together to fully exhibit the character of the locus between them. Unfortunately the body of platinum from which I made my alloys was not rigorously pure, an annoyance which in the course of other parts of my work I had occasion to regret. So far as the present investigation goes, however, the hurtful effect of the impure platinum body is *nil*. It will appear even more clearly below, that the law to be investigated is independent of the ingredients of the platinum alloy, except in so far as they modify its electrical conductivity. Alloying here is merely a means of modifying resistance, and the results are studied with regard to the resistance produced, not with regard to the way in which resistance is modified.

6. In making the alloys a weighed amount of platinum was fused down on a lime hearth before the oxyhydrogen flame. The foreign ingredient was then added, and the product after cooling rolled down and drawn to wire form. The initiated will know that accidents are not infrequent and that the tedious operations must often be repeated. The details of fusion and other manipulation are given in the Bulletin. To make the electrical measurement, selected parts (length 30^{cm}, diameter $0{\cdot}045^{cm}$) of the wires were annealed at a red heat and then wrapped in a single layer around a little cylinder of porcelain (length 2^{cm}, diameter $0{\cdot}45^{cm}$) in such a way that the spires of the helix did not touch. The ends were appropriately fused to copper terminals. The little helix was then introduced into the space of constant temperature of my *boiling tube*, and consecutively heated to 25°, 100° (steam), 357° (mercury vapor).

The results of the measurements are given in the following table. The series contains 57 alloys, of which Δ_0 denotes the density and s_0 the zero specific resistance. The table contains two values for the temperature coefficient α, the first of which, α_0^{100}, holds for the mean increase between 0° and 100°, the second between 0° and 357°, linear equations presupposed.

The wires A, B, C, are of the same platinum body (B), purified by long-continued intense fusions on lime, before the oxyhydrogen blow-pipe.

The relation of these data to each other may be exhibited graphically, and since α_0^{100} is very nearly $f'(o) : f(o)$, the following chart, figure 1, preferably represents α_0^{100} as a function of s_0. A few unmistakably exceptional values of α_0^{100} are either rejected or replaced by α_0^{357}, the justification of which is shown in the Bulletin.

The chart shows clearly, I think, that the alloys of platinum may be regarded as a class of materials possessing generic electrical properties: for the effect of alloying platinum with small amounts (<10 per cent) of any other metal, is a variation of temperature-coefficient in a way which is independent of the

TABLE III.—*Showing the electrics of platinum alloys.*

No.	Metal alloyed to Platinum.	Δ_0	s_0	$10^3 \times a_0^{100}$	$10^3 \times a_0^{357}$
A	Platinum	----	12·0	2·90	2·65
C	Platinum	----	13·3	2·52	2·58
B	Platinum	21·31	14·9	2·30	2·22
1	Gold	21·29	18·5	1·78	1·62
2	Gold	21·22	22·1	1·45	1·33
3	Gold	21·17	24·7	1·27	1·09
4	Silver	21·16	19·1	1·80	1·61
5	Silver	20·99	22·3	1·46	1·02
6	Silver	19·40	34·0	1·02	0·71
7	Palladium	21·01	18·9	1·75	1·62
8	Palladium	20·54	20·9	1·53	1·48
9	Palladium	19·91	23·9	1·29	1·18
10	Iridium	21·27	19·4	1·72	1·61
11	Iridium	21·28	20·4	1·63	1·50
12	Iridium	21·32	23·6	1·28	1·21
13	Copper	20·68	31·8	0·89	0·83
14	Copper	20·60	33·6	0·80	0·72
15	Copper	18·80	63·6	0·20	0·20
48	Copper	20·92	25·3	1·27	1·14
49	Copper	19·56	53·6	0·29	0·15
16	Nickel	20·69	21·7	1·68	1·46
17	Nickel	19·89	26·8	1·34	1·19
18	Nickel	18·75	32·8	1·05	0·87
19	Cobalt	20·59	28·6	1·09	1·04
20	Cobalt	19·84	39·6	0·89	0·74
21	Cobalt	19·33	30·7	1·57	1·30
40	Cobalt	19·10	44·6	1·30	0·83
41	Cobalt	20·99	24·0	1·39	1·27
22	Iron	20·63	36·3	0·74	0·74
23	Iron	20·33	41·8	0·66	0·64
24	Iron	19·59	59·9	0·37	0·36
42	Iron	19·75	62·5	0·44	0·39
43	Iron	20·89	28·8	1·12	0·98
50	Steel	19·58	60·2	0·44	0·39
51	Steel	19·95	49·2	0·77	0·64
25	Chromium	20·91	27·4	1·14	1·06
26	Chromium	20·51	40·9	0·65	0·62
27	Chromium	20·16	52·4	0·56	0·49
44	Chromium	20·76	31·1	0·95	0·87
28	Tin	21·11	21·5	1·55	1·49
29	Tin	20·97	25·6	1·27	1·20
30	Tin	20·45	39·8	0·69	0·66
31	Aluminium	20·46	25·3	0·85	1·32
32	Aluminium	20·72	21·2	1·56	1·50
33	Manganese	20·81	25·6	1·28	1·14
34	Manganese	19·43	48·9	0·52	0·43
35	Molybdenum	21·26	16·0	2·13	1·94
36	Molybdenum	21·26	19·0	1·76	1·69
45	Molybdenum	21·30	16·4	2·06	1·88
37	Lead	21·18	14·6	2·28	2·23
46	Lead	21·24	17·0	2·02	1·82
38	Antimony	20·75	29·5	1·11	1·09
39	Bismuth	21·18	----	----	----
47	Bismuth	21·33	15·83	2·10	2·03
52	Zinc	20·10	44·2	0·51	0·32
54	Zinc	20·98	24·5	1·34	1·14
53	Cadmium	(21·3)	----	----	----

special ingredients of the alloy, and which depends only on the resistance-position of this alloy in the class. I venture to assert therefore that the arrangement of points is in accordance with a definite underlying law, with reference to which exceptional data are to be interpreted. The law in question appears to me particularly noteworthy as being among those which spe-

1.

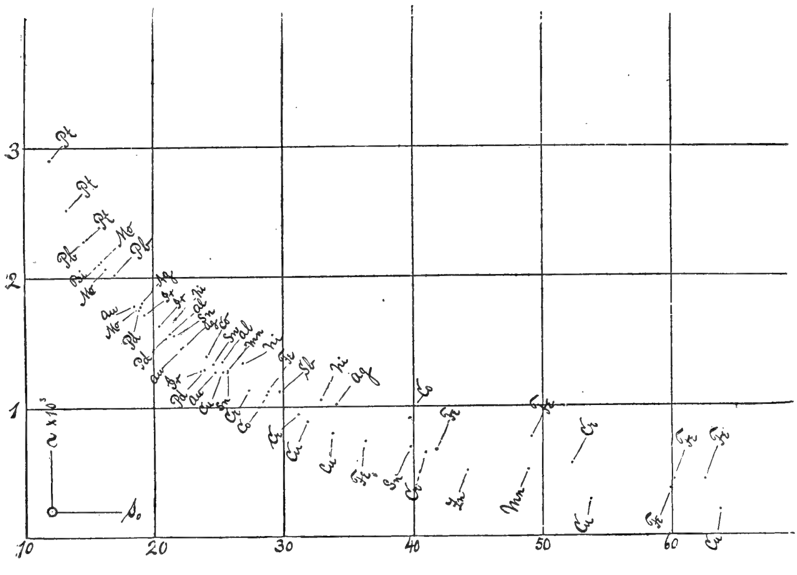


FIGURE 1.—Showing the relation between temperature-coefficient (a) and electrical resistance (s_0), in case of platinum alloys.

cially hold for the solid state. In his experiments on the conductivity of solid mercury, C. L. Weber* found its resistance to increase fourfold in virtue of fusion. Simultaneously with this variation, the temperature-coefficient of solid mercury (0·00455) falls to the relatively very low value (0·000927 between $-30°$ and $+45°$) which holds for the liquid metal. Weber points out the close approximation of the temperature coefficient of solid mercury to that of the other solid metals, and infers even closer agreement at temperatures sufficiently below the melting point of mercury. It is in a similar sense that in §1 I referred the properties to be investigated in this paper to a class of alloys characterized by high melting points.

* C. L. Weber, Wied. Ann., xxv, p. 245, 1885. The large variation of resistance at the melting point, observed in case of mercury and other metals and alloys (K, Na, etc.), suggests the striking adaptability of these substances for experiments on the relation between melting point and pressure; or in general on the continuity of solid and liquid state. Change of resistance is here the criterion of fusion.

7. Having thus obtained some general notions of the dependence of $f'(0)/f(0)$ on $f(0)$, it is in place to inquire more fully into the form of this dependence. I will proceed in a manner similar to that employed in §4, and postulate the hyperbolic equation $(x+l)(y+m)=n$. Availing myself of the chart, figure 1, selecting for preliminary computation a set of coördinates as carefully as possible from it,

$x=11{\cdot}7$	$y=0{\cdot}00300$
$20{\cdot}0$	164
$50{\cdot}0$	050

I find the constants l, m, n to be

$$l=-0{\cdot}1360, \quad m=0{\cdot}0002548, \quad n=0{\cdot}03764.$$

The values found for l, m, n are exceedingly significant. Since x varies between 10 and 70, l is in general much less than one per cent of x. This observation at once suggests the assumption of a simpler form of equation in which $l=0$. Again the positive character of m indicates that larger values of α_0^{100} would tend still further to simplify the equation $(x+l)(y+m)=n$. But $\alpha_0^{100} > \alpha_0^{357}$ follows from the experiments; hence also

$$f'(0)/f(0)=\alpha>\alpha_0^{100},$$

and therefore the postulation of $x(y+m)=n$ is altogether warranted.

To obviate the necessity of a complete recalculation of α, I used the following method of passing from α_0^{100} and α_0^{357} to α. If the values s, s', s'', correspond respectively to t, t', t'', and if

$$\frac{s}{1+\alpha t+\beta t^2}=\frac{s'}{1+\alpha t'+\beta t'^2}=\frac{s''}{1+\alpha t''+\beta t''^2},$$

it follows that

$$\alpha=\frac{(s'-s)(st''^2-s''t^2)-(s''-s)(st'^2-s't^2)}{(st'-s't)(st''^2-s''t^2)-(st''-s''t)(st'^2-s't^2)},$$

from which it is easy to deduce $\alpha-\alpha_0^{100}$ in terms of $\alpha_0^{100}-\alpha_0^{357}$. Now $st''-s''t=D''$ and $st'-s't=D'$ are already known from the earlier computations; and when a correction only is sought $s''t^2$ and $s't^2$ may here be neglected as compared with st''^2 and st'^2, respectively, t being small in comparison with t' and t''. Hence

$$\alpha-\alpha_0^{100}=\frac{\alpha_0^{100}-\alpha_0^{357}}{t''^2/t'^2\ D'/D''-1},$$

which equation, since the fraction $(t''/t')^2$ is constant, is a convenient form, and much of the correcting may be done mentally. I may add that the three quantities α_0^{100}, α_{100}^{357}, α_0^{357}

have similarly simple approximate relations to each other; for instance,

$$\alpha_0^{100}-\alpha_0^{357}=(t''-t'/t''-t)\ (\alpha_0^{100}-\alpha_{100}^{357}),$$

and since the fraction $(t''-t'/(t''-t)$ is constant, such reductions also are mental. I observe finally that the effect of these corrections is only a few units of the last figure. The methods are therefore sufficient.

8. Having made this preliminary survey, the data are available for the calculation of m and n by the method of least squares. It is expedient, however, before doing so, to put the postulated equation under the form

$$f'(0)/f(0)=n\,.\,1/f(0)-m,$$

where $1/f(0)$ is the zero value of the electrical conductivity of the alloy whose temperature-coefficient is α. This equation when operated on by the method of least squares does not give inordinate preference to high values of specific resistance; and since such high values can not be warranted with a greater degree of accuracy than the low values, the said equation may most expediently be made the basis of computation.

The following table contains the results and is intelligible without further explanation. The alloys 10, 11, 12 which I insert for completeness, were added subsequently to the calculation.

The probable errors of m and n indicate that the inaccuracy is largely incurred in the measurement of $f'(o)/f(o)$. The constant n is much more fully warranted.

9. Endeavoring to describe the platinum alloys as a class possessing generic electrical characteristics it is permissible to abstract from the minute and isolated behavior of the individual alloy. It appears that the electrical temperature-coefficient $(f'(o)/f(o))$, varies as a linear function of conductivity $(1:f(o))$, throughout the whole of the enormous variation of electrical resistance (10 to 65 microhms, c. c.), presented by platinum alloys not too highly alloyed (<10 per cent). In other words, if at t°, the specific resistance of a platinum alloy be denoted by $f(\chi,t)$, where t symbolizes temperature and χ is a variable parameter, then

$$f(\chi,0)\ (f'(\chi,0)/f(\chi,0)+0{\cdot}000194)=0{\cdot}0378.$$

It is perhaps not superfluous to remark in passing that if instead of the arbitrary temperature 0° C., some other value more in keeping with the qualities of platinum alloys had been selected, the constants m and n would present different values; and it is conceivable that correlated values of $f(t)$ and $f'(t)$ may exist for which the constant m is annulled, and for which the given equation takes the simple form $xy=n'$.

TABLE IV.—*Electrics of platinum alloys. Digest* $f(0)\ (f'(0)/f(0)+m)=n$.

No.	$f(0)$.	Observed $(f'(0)/f(0))\times 10^3$.	Calculated $(f'(0)/f(0))\times 10^3$.	Error $\times 10^3$.	Metal alloyed to platinum.
A	12·0	2·96	2·94	+ 2	Pt
C	13·3	2·50	2·66	—16	Pt
B	14·9	2·33	2·34	— 1	Pt
1	18·5	1·84	1·84	— 1	Au
2	22·1	1·49	1·51	— 2	Au
3	24·7	1·33	1·34	— 1	Au
4	19·1	1·87	1·79	+ 8	Ag
7	19·4	1·76	1·75	+ 1	Pd
8	20·4	1·67	1·66	+ 1	Pd
9	23.6	1·30	1·40	—10	Pd
10	19·4	1·76	1·75	+ 1	Ir
11	20·4	1·67	1·66	+ 1	Ir
12	23·6	1·30	1·40	—10	Ir
13	31·7	0·91	1·00	— 9	Cu
14	33·6	0·83	0·93	—10	Cu
15	63·6	0·21	0·40	—19	Cu
48	25·3	1·31	1·30	+ 1	Cu
49	53·6	0·34	0·51	—17	Cu
16	21·7	1·75	1·55	+20	Ni
17	26·8	1·39	1·21	+18	Ni
18	32·8	1·11	0·96	+15	Ni
19	28·6	1·11	1·13	— 2	Co
20	39·6	0 93	0·76	+17	Co
41	24·0	1·43	1·38	+ 5	Co
22	36·3	0·74	0·84	—10	Fe
23	41·8	0·67	0·71	— 4	Fe
24	59·9	0·37	0·44	— 7	Fe
42	62·5	0·46	0·41	+ 5	Fe
43	28·7	1·21	1·12	+ 9	Fe
50	60·2	0·46	0·43	+ 3	Steel
51	49·2	0·81	0·58	+23	Steel
25	27·4	1·17	1·19	— 2	Cr
26	40·9	0·66	0·73	— 7	Cr
27	52·3	0·58	0·52	+ 6	Cr
44	31·1	0·98	1·02	— 4	Cr
28	21·5	1·57	1·56	+ 1	Sn
29	25·6	1·29	1·28	+ 1	Sn
30	39·9	0·70	0·75	— 5	Sn
32	21·2	1·58	1·59	— 1	Al
33	25·6	1·33	1·28	+ 5	Mn
34	48·9	0·55	0·58	— 3	Mn
35	16·0	2·20	2·18	+ 2	Mo
36	18·9	1·78	1·80	— 2	Mo
45	16·4	2·12	2·11	+10	Mo
37	14·6	2·30	2·38	— 8	Pb
46	17·0	2·09	2·03	+ 6	Pb
38	29·5	1·12	1·09	+ 3	Sb
47	15·8	2·12	2·19	— 7	Bi
52	44·2	0·57	0·66	— 9	Zn
54	24·5	1·41	1·35	+ 6	Zn

$$m=0·0001939\pm0·0000233$$
$$n=0·03778\quad\pm0·00054$$

10. It is desirable finally to give as graphic an exhibit of the results taken collectively, as possible. Unfortunately any scale which clearly presents the results for gold, silver and copper, will crowd the results for platinum and the iron-carburets; and vice versa. Perhaps the following chart, fig. 2, will

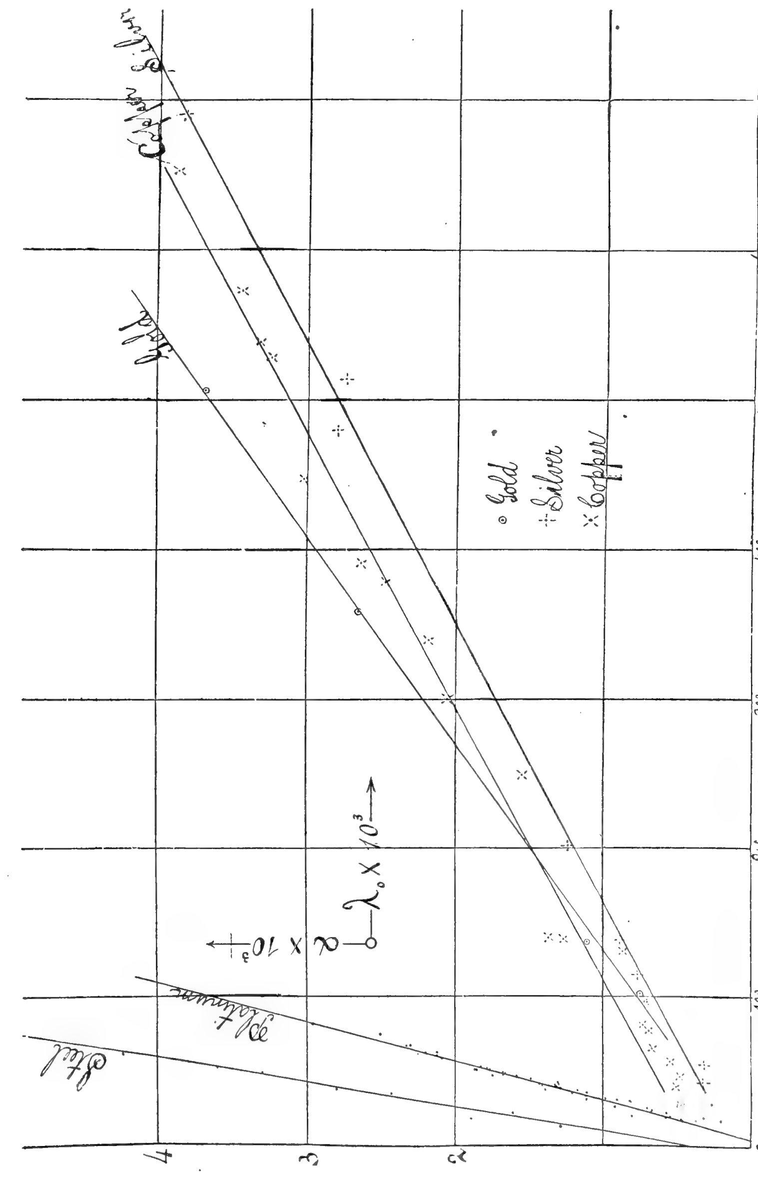


FIGURE 2.—Diagram of the relation between temperature coefficient (α) and conductivity (λ_0) for certain low percentage alloys.

represent the relation here involved. The constants of the lines drawn through the points are given at the end of the tables in §§ 3, 4 and 7. In the cases of silver, of gold, of platinum and of steel, the distribution of the points with reference to these lines is satisfactory, when the errors introduced by the mechanical treatment, by variations of hardness, and particularly by imperfect homogeneity are justly taken into account. In many cases, moreover, the percentage presence of foreign ingredient is greater than that specified in § 1. As all this is even more frequently the case with alloys of the oxydizable metal copper, the line computed by the method of least squares does not fairly represent these observations. The exceptional points here are the alloy of Cu with 22·4 per cent Ag, and the brasses with 23·6 per cent, 29·4 per cent and 42·1 per cent Zn. If these high per cents are rejected, the line for copper* will agree more nearly in character with the lines for gold and for silver, as it will tend more nearly to intersect the origin of coördinates (smaller numeric m). Applying the method of least squares for the case in which the inadmissible copper alloys are withdrawn, I find $m=-0{\cdot}278$ and $n=+0{\cdot}005655$, and of course a better agreement between observed and calculated a throughout. In figure 2, however, I have nevertheless inserted the line calculated for all the copper alloys in hand.

An interesting peculiarity of the steel line is that it leads to a larger value for the temperature-coefficient of iron† than that hitherto accepted. Comparisons of absolute values must however be made with caution, because of the great variety of electrical standards used by different observers. The high temperature-coefficient of iron is in conformity with relatively high values usually shown by alloys containing iron (cf. fig. 1.)

I desire finally to advert to the occurrence of the relatively *small* values of the constant, m, as computed for each of the series of silver, copper, gold, platinum and steel alloys. There is a marked tendency in all the cases stated to intersect the coördinate axes very near the origin. Inasmuch therefore as (§ 1) $a=f'(\chi,0)/f(\chi,0)$ and $\lambda_0=1/f(\chi,0)$, the slopes of these lines are very nearly equal to $f'(\chi,0)$; or more rigorously to $f'(0,0)$, since their true nature is that of an initial tangent (cf. § 3.) In § 11 it appears that I am not asserting, however, that these lines do pass through the origin.

* Those who have worked with copper alloys, will know the extreme difficulty encountered in making the individual points conform to any uniform curve. The data usually make up a diagram of very broken lines, as in the above work of Matthiessen, and in results of Dr. Strouhal and myself. Further comment is made in the Bulletin.

† In his research on the conductivity of iron, Auerbach (Wied. Ann., viii, p. 479, 1879), discusses reasons for the exceptionally high value of the temperature-coefficient of iron.

11. Taking the results collectively, they point to a limit below which in the case of solid metals and at ordinary temperatures, neither electrical conductivity nor temperature-coefficient can be reduced; whence it appears that a lower limit of both conductivity and temperature-coefficient is among the conditions of metallic conduction, not to say of metallic state.* These considerations are suggestive and I shall therefore endeavor to make what I have in mind clearer. In the case of conduction in metals (solid or liquid) the effect of temperature is a decided decrease of conductivity, continuing apparently, as temperature increases, indefinitely.† In the case of conduction in non-metallic elements‡ or in electrolytes (solid or liquid) on the other hand, the effect of temperature is a decided increase of conductivity, which supposing the liquid state to be retained, continues as temperature increases. Hence conduction in metals is distinguished from conduction in electrolytes in this respect, that if the temperature coefficient in the one case (electrolytes) be regarded positive, its value in the other case (metals) must be negative. This leads me to inquire into the possible occurrence or the nature of a class of substances whose temperature-coefficient is zero; a class of substances in other words in which the metallic and the electrolytic modes of electric conduction may be supposed to converge.§

The point which I have in view, viz: the possibility of a continuous transition from metallic to electrolytic conductivity gains much in reasonableness by associating with good metallic conductivity the correlative property of optic opacity. Relations between electricity and light have been investigated and many experimental facts are known. Maxwell's electro-mag-

* Recent researches of v. Ettingshausen and Nernst and of C. L. Weber (Wied. Ann., xxxiv, p. 582, 1888), show that the resistance-temperature coefficient of bismuth is often negative between 0° and 100°. Edward Weston has made alloys of copper, ferro-manganese and nickel of which this temperature-coefficient is nearly zero or even negative (Science, xii, p. 56, 1888). These exceptions, the underlying cause of which is probably secondary and to be referred to structural or crystalline modification, emphasize the vast amount of evidence in favor of the normal behavior given in the text. I may add, for instance, that the temperature-coefficient of glasshard steel between 0° and 100°, would be nearly zero because of annealing.

† Following Benoit (C. R., lxxvi, p. 342, 1873) the electrical resistance of all metals increases with temperature at an accelerated rate, except in the case of platinum and palladium, where the rate of increase is retarded. Benoit observes at temperatures limited by the boiling point of zinc.

‡ Matthiessen (Pogg. Ann., ciii, p. 428, 1858), W. Siemens (Wied. Ann., x, p. 560, 1880) and others (Bergmann, Kemlein, Muraoka) find this to hold for modifications of carbon. Similar increases of conductivity are usually observed in the case of selenium and tellurium (Hittorf, W. Siemens, Mattheissen, and many others); but the relations here are complicated. Quite recently Duter (C. R., March 19th, 1888) has shown that sulphur conducts at its boiling point. It is this investigation which I have specially in mind in the text.

§ Something of the kind may perhaps occur in the case of some natural sulphides, but it is not open for systematic study and its nature is obscure.

netic theory of light furnishes a theoretical basis for the fact that true conductors are exceedingly opaque. The resistance of solid metals, however intensely they may be heated, is found to increase so long as temperature increases. Nevertheless the careful experiments which Govi* made to interpret an erroneous result of Secchi,† prove that solid metals even in extreme states of white heat remain opaque. In the case of liquid metals at extreme white heat the case is not so definitely established; and the question relative to the ultimate transparency of liquid metals at very high temperatures is an open one.‡ It is in the direction of ultimate transparency that the observed continuous increase of resistance with temperature seems definitely to point.

It is reasonable to infer that the transition from opaque to transparent§ will take place in the region of the critical temperature. At least such transition must ultimately occur; and I am led to conjecture that the said transition from opaque to transparent will be accompanied by a change of the values of the electrical temperature coefficient, passing from the negative value which holds for the liquid metal, to the positive value which will probably hold for the gaseous metal, continuously through zero. The fact that conduction in gases is of an electrolytic nature was proved by Varley,‖ who showed that after the polarization of the electrodes is overcome, gases obey Ohm's law. The electric *strength* of air is known to diminish rapidly as temperature is increased. Working with hot gases carefully insulated and protected from flames, Maxwell¶ was unable to obtain conduction either in hot gases like air or in hot metallic vapor like Hg or Na. At higher temperatures (red heat) the researches of Blondlot,** confirming the observations of E. Becquerel,†† prove that hot gases are conductors, and that at temperatures sufficiently high $\frac{1}{1000}$ volt is enough to set up a current. Hence in their thermal relations also, gases ultimately partake of the nature of an electrolyte, and the occurrence zero value of the temperature coefficient may be reasonably associated with the critical temperature of the metallic liquid, passing continuously from the liquid into the gaseous state.

* Govi, Comptes Rendus, lxxxv, p. 699, 1877.

† Secchi, Comptes Rendus, lxiv, p. 778, 1867.

‡ W. Ramsay, Chem. News, lv, pp. 104 and 175, 1887; Turner, ibid., p. 163, 1887; Professor T. Sterry Hunt has given the question some attention. Kundt's recent experiments (Wied. Ann., xxxiv, p. 469, 1888), on the refractive index of metals will doubtless lead to more definite results than the data now in hand.

§ The jet of liquid hydrogen escaping from Pictet's apparatus appeared steel-blue, and was opaque for a distance of about 12^{cm}.

‖ Varley, Proc. Roy. Soc., xix, p. 236, 1871.

¶ Maxwell, Elementary Treatise on Electricity, ed. by Garnett, 1881, §§138, 139.

** Blondlot, Comptes Rendus, xcii, p. 870, 1881; ibid., civ, p. 283, 1887.

†† E. Becquerel, Comptes Rendus, lv, p. 1097, 1867.

ART. XLIV.—*On the Puget Group of Washington Territory;* by CHARLES A. WHITE.

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ABOUT two years ago, Prof. J. S. Newberry placed in my hands for study a small collection of fossil mollusca which he had obtained from the coal-bearing formation in Puget Sound basin in Washington Territory. This collection represents a hitherto unpublished brackish-water fauna, which characterizes a formation that possesses unusual interest. All the discovered species of this fauna will be described and illustrated in Bulletin 50 of the U. S. Geological Survey, where also the formation will be discussed. Twelve species have been recognized, of which the following is a list: *Cardium* (*Adacna?*)——?, *Cyrena brevidens*, n. s., *Corbicula Willisi*, n. s., *C. Pugetensis*, n. s., *Batissa Newberryi*, n. s., *B. dubia*, n. s., *Psammobia obscura*, n. s., *Sanguinolaria? caudata*, n. s., *Teredo Pugetensis*, n. s., *Neritina* ——?, *Cerithium* ——? and an undetermined gasteropod.

The formation from which these fossils were obtained is known to occupy a large part of Puget Sound basin, and to extend upon the western flank of the Cascade range, which forms the eastern side of the basin; but all the boundaries of the area which it occupies are not at present known. Besides these strata which lie to the west of the Cascade range, other similar deposits are found upon its eastern flank, as well as at certain localities among its higher mountains. All these deposits are believed to belong to one and the same formation, although those within, and east of, the Cascade range have not yet furnished any molluscan fossils similar to those found upon the western side of the range. Certain unique features of the fauna referred to show that the strata in which the remains were found were deposited in a body of water which was quite separate from that in which was deposited any one of the coal-bearing formations in the Pacific Coast region or elsewhere. Its zoological character indicates that the body of water in question was an estuary; and the extent of the district within which the deposits have been found shows that that estuary was a very large one.

The most complete information that has yet been published concerning this formation appeared in volume XV of the reports of the Tenth U. S. Census, pp. 759–771, plates LXXXII–CII. That publication, which is entitled "A Report on the Coal Fields of Washington Territory," is by Mr. Bailey Willis, who accomplished the work upon which his report is based under

the auspices of the Northern Transcontinental Survey. The special object of his report having been the presentation of the coal resources of that region, the discussions are confined mainly to its coal-bearing formations; and the report therefore does not embrace a full account of the geology of the whole region. Still, Mr. Willis has given some comprehensive facts as well as many elaborate details concerning this formation in the report referred to; and as my own field labors upon the Pacific coast have not extended to the northward of the Columbia river, my knowledge of many of the facts which are stated in the following remarks has been derived from him, and from Professor Newberry.

The orogenic elevations of the Pacific Coast region extend in two lines which are approximately parallel with each other and with the coast. The eastern line consists of the Sierra Nevada in California and of the Cascade range in Oregon and Washington Territory. The western line, known as the Coast range in California, is more or less distinctly recognizable through western Oregon, and extends northward of the Columbia river into Washington Territory; but it there sinks to low hills before reaching the Olympic cluster of mountains, which forms the northern end of the line. This cluster is a prominent feature of that district, its higher peaks rising to more than 8000 feet above the sea level.

The relief of this great strong-featured Pacific Coast region is the product of several uplifts, differing in time, extent and locality, the whole history of which is not yet clearly understood but the facts of interest in this connection may be provisionally stated as follows. The Cascade range, which has been recognized as distinct in structure and origin from the Sierra Nevada range, although in a general line continuous with it, has been considered to be itself simple; but it is in reality quite complex. In Oregon it is composed of erupted material, often of great thickness, which has been observed to rest upon nearly horizontal sedimentary strata of Cretaceous age; and in southern Washington Territory it consists of enormous masses of erupted rocks overlying highly flexed sedimentary strata of late Mesozoic or early Tertiary age. In the northern half of the same Territory the range is made up entirely of granite, crystalline schists and volcanic rocks. As bearing upon the subject in hand, it may be stated here that the Tertiary rocks, which prevail in the Coast range generally seem to be wanting in the Olympics which, in this respect and in their composition, resemble the northern portion of the Cascade range.

Between the two long lines of orogenic elevation before referred to, lie the great valleys of the Sacramento and San Joa-

quin rivers in California, of the Willamette in Oregon, and of Puget Sound (known as Puget Sound basin) in Washington Territory. The latter valley was the scene of deposition of the coal-bearing series of strata which is characterized by the molluscan fauna already mentioned.

Mr. Willis describes this formation as consisting of "alternating beds of yellow and fine grained sandstones and very fine arenaceous shales interstratified with many beds of carbonaceous shale and coal; the individual strata of sandstone and shale, from 20 to 200 feet thick, maintain the same general character wherever observed." He further says that a section measured near the town of Wilkeson in Puget Sound basin "gives a minimum thickness of 13,200 feet, with a probable maximum of 14,500 feet." The surprise that one feels upon learning of the extraordinary thickness of this estuary deposit is increased by Mr. Willis's statement that, so far as he could observe, the contained molluscan fauna ranges vertically through the whole formation.

This is surely a remarkable deposit for one of estuary origin, but it is so regarded in consideration of the following facts: No trace of an open sea fauna has been found in it, while all the molluscan remains that have been found in it are related to estuary forms. These remains embrace species of the Corbiculidæ, the members of which family are known to range from brackish to fresh waters. These forms are associated with certain others whose living congeners are known to range from marine to brackish waters but not into fresh waters; and the strata of this deposit contain an abundance of vegetable remains, which doubtless came from local swamps and adjacent shores.

No specimens of this fauna have yet been discovered beyond the present limits of Puget Sound basin, nor in any other formation than those from which Professor Newberry's collection was made. But if, as is inferred from a general similarity of lithological characters, the absence of marine fossils, the presence of coal beds and of identical species of plant remains, and from similarity of position with relation to older and later formations, the deposits which are found upon the eastern side, as well as within the body, of the Cascade range in southern Washington Territory, constitute parts of the same formation which is found upon the western side, the scene of its deposition extended much beyond the limits of Puget Sound basin.

This conclusion of course implies that the portion of the Cascade range upon which those strata are found was not then elevated, as was the northern portion, and that the outline of the area within which this deposit was made was very different from

what would be suggested by any of the present topographical features of the region. That the present topographical features of that region differ greatly from those which prevailed during the Puget epoch is indicated by other observations of Mr. Willis. For example, he noted the absence of the Puget Group high up in both the Olympic, and the northern Cascade mountains, which leads him to believe that while that formation was being deposited, the former mountains constituted an island, and the latter, a peninsula. It is hardly to be supposed, however, that the topographical features of that region were permanent throughout the whole of the Puget epoch, because the range of the molluscan fauna through the whole thickness of the formation, as already mentioned, indicates that there was a constant subsidence over the whole area within which the deposit took place, during the whole time of its accumulation. Certain topographical changes in that neighborhood at least, must have accompanied such a subsidence.

In the report of Mr. Willis, already referred to, he not only regards this formation as equivalent with the Laramie Group, but he provisionally applies the same name to it. His reasons for doing so, in addition to the fact that, like the Laramie, this group apparently rests directly upon upper Cretaceous marine strata, appears in the following paragraph which he has kindly furnished me from an unpublished report of his upon a district which lies to the eastward of Puget Sound basin.

"*The Laramie? of the Wenatchie Valley.*"

"The Wenatchie river cuts a section across unmetamorphosed conglomerates and sandstones bent in broad folds over axes having a general north and south trend. This formation flanks the Peshastan range on both sides, occurring on the south on Schwak creek, and in the Klealim valley, and forms some of high crests of the Cascade range north of Natchez. It is the last formation deposited before the elevation of the Cascade range and its spur, the Peshastan, and is thus identified, as well as lithologically and in its stratigraphic relations, with the Puget Sound Coal measures, the latter having been assigned to the Laramie by Prof. J. S. Newberry on the evidence of the leaf impressions."

I think that all the known evidence is strongly in favor of the view taken by Professor Newberry and Mr. Willis as to the equivalency and probable contemporaneity of the Puget Group with the Laramie; but it may be regarded as certain that these two formations were deposited in separate bodies of water and under materially different conditions; and that they were separated by a land area of considerable breadth. The area, however, was not so broad as to make it unreasonable to suppose

that an arboreal flora extended entirely across it, and scattered its autumnal leaves into the Laramie sea upon the one hand and into the Puget estuary on the other. Possibly it may yet appear that terrestrial vertebrate, and molluscan faunas also extended across the same area by the discovery of their remains in both the Laramie and Puget groups.

Besides the evidence which is furnished by the character of the gill-bearing fossil mollusca of the Laramie and Puget groups respectively that they were deposited in separate bodies of water, satisfactory evidence exists that the Laramie outlet was upon the Atlantic side of the continent, and that the Puget outlet was upon the Pacific side. Admitting that these conditions existed there seems to be little probability that the two faunas had a common origin. Under such circumstances I think it better to use separate names for the two formations; and I have accordingly proposed the name of Puget Group for the formation which forms the subject of this article.

As to what were the original boundaries of the Puget estuary deposit comparatively little is definitely known, as already intimated. It is probable also that much will always remain unknown upon this point owing to the great erosion which the strata have suffered, and to the presence of large portions of the volcanic outflows which have so largely covered them. Taking into consideration the extreme points at which strata of this group have been found, including those which lie to the east of, and among the Cascade mountains, the present indications are that the Puget Group originally occupied an area of several thousand square miles.

That the body of water in which the Puget Group was deposited was an estuary, and not a land-locked sea, as was the Laramie, is indicated, as already shown, by its molluscan fauna.* But in what manner the Puget estuary was separated from the open ocean we have as yet little information. A natural inference would be that the Olympic island formed part of such a barrier, but the discovery of marine fossils in the valley of Dwamish river, the strata inclosing which were presumably formed contemporaneously with at least a portion of the Puget Group, would seem to show that the estuary barrier was, a part of the time, at least, to the eastward of Olympic island.

Although the contemporaneity of the Puget and Laramie groups apparently need not be questioned, the stratigraphical relation of the former to the Téjon Group, which is presumably of approximately the same age, has not been satisfactorily determined. Vertebrate and vegetable paleontology have fur-

* The apparent absence of this peculiar fauna from the more eastern strata suggests that they were deposited nearer to the influx of fluviatile waters, which being therefore entirely fresh did not afford a congenial habitat for the species which prevailed in the western and brackish part of the estuary

nished no evidence upon this point. The invertebrate remains which each formation has furnished afford no means of comparison because those of the Puget Group are estuarine and those of the Téjon Group marine: and because the estuarine types of molluscan life are always of little if any value as indicating geological age. Therefore we are reduced to stratigraphic evidence alone in attempting to correlate the Puget, with the Téjon Group.

Mention has just been made of the discovery of strata containing marine fossils at a locality on Dwamish river in Puget Sound basin, and not far from typical exposures of the Puget Group. A considerable proportion of the fossils found there have been identified with Téjon species, and those Dwamish valley strata doubtless represent a part of the Téjon Group.

Mr. Willis, who has studied the stratigraphy there in connection with his work before referred to, regards the position of these marine strata with reference to those of the Puget Group as having been deposited not earlier than those of the upper portion of that group. This view of the stratigraphical relations of the Dwamish river strata with those of the Puget Group, together with the fact that the fossils of the former are of marine origin, suggests that they were deposited in marine waters towards the close of the great subsidence that accompanied the deposition of the Puget Group, and indicates that the latter group is a local, although a large, chronological representative of a part, or the whole, of the Chico-Téjon series.*

Now if the strata of the Puget Group were deposited, even in part, contemporaneously with the Chico-Téjon series, it is probable that some of the species of that series which were capable of entering brackish waters may yet be found in the Puget strata, and that some of the Puget fauna which were capable of entering marine waters may yet be found associated with Chico-Téjon species. As a matter of fact, however, no evidence of such a commingling of the species of the two faunas has yet been discovered. So far, therefore, we have no paleontological evidence of the contemporaneity of the Puget Group with the Chico-Téjon series.

Although no serious doubt is entertained that the Puget Group was deposited in estuarine waters there are certain facts which are somewhat perplexing when considered in connection with an acceptance of that view. The known area within which strata of that group occur shows that the Puget estuary was of such great extent that it is difficult to understand how so large a body of water could have been uniformly kept so

* It also seems to indicate that the western barrier of the Puget estuary was at that time and place, not far from the middle of the present Puget Sound basin, but it is probable that the position of the barrier was shifted from time to time, during the existence of the estuary.

nearly fresh as to afford a congenial habitat for such a molluscan fauna as it is known to have possessed, and as was necessary for the accumulation of the great thickness of strata in which the remains of that fauna are found, during so long a period of time.

That is, it is difficult to understand how that comparatively narrow portion of the continent between the then existing Laramie hydrographic basin on the east, and the Puget estuary on the west could have furnished a sufficient flow of fluviatile water to keep nearly fresh so large an estuary, and keep off the encroachment of adjacent marine waters. Even so large a flow as is now discharged by the Columbia would seem to have been insufficient unless the outlet of the great estuary was greatly narrowed by land barriers.

Again, the evidence presented by Mr. Willis, and also that afforded by the fossils, which range without material change through a large part of the vertical series, seems to be conclusive that essentially uniform estuarine conditions were preserved over the whole area now occupied by the Puget Group from the time of the deposition of its earliest, to that of its latest strata. This evidence also discloses the remarkable fact that during that time there was a constant subsidence over the whole area, until it had reached a maximum of not less than twelve thousand feet.

It is certainly difficult to understand how so great a subsidence could have taken place without such a simultaneous elevation of the adjacent land area as would have materially changed the character and uniformity of the supply of fluviatile waters to the estuary, or have added a land area to the westward of it. Indeed, it is difficult to understand how even a less subsidence could have taken place without materially modifying the character of the great estuary itself, or even submerging its whole area beneath marine waters.

The biological relations of this Puget fauna to other faunas possess peculiar interest. For purposes of comparison one instinctively turns to the molluscan fauna of the Laramie Group; but in doing so important differences appear. It is true there are two species of Corbicula in the Puget fauna that are so closely like Laramie forms as to suggest specific identity upon casual examination; but the differences between the two faunas are strikingly shown by the family and generic characters of the other members of the Puget fauna as compared with the Laramie fauna.

For example, a species of Teredo has been found in the Puget Group, but no member of the Teredinidæ has yet been found in the Laramie. Two species of the Puget fauna are referred to the Tellinidæ, but no member of that family has

yet been found in the Laramie. But the generic form which gives an especially unique character to the Puget fauna is that of Batissa. This genus has not hitherto been known to occur in North America, in either a fossil or living condition; nor has it been found nearer to this continent than certain of the Pacific islands. Still the hinge characters observable in these Puget estuary specimens leave no room for reasonable doubt that they are strictly congeneric with Batissa. Indeed a species of that genus which is now living upon the Fiji Islands is closely related to this fossil form.

Certain interesting relationships between Asiatic and North American faunas have been noticed by naturalists, which are recalled by this occurrence of Batissa in the Puget fauna. Assuming that these relationships are those of genetic succession, we naturally desire to know the direction of the lines along which their geographical dispersion took place. For example, was it toward, or from the present North American continent that the dispersion of Batissa has occurred? If it was from this continent, it is remarkable that none of its progeny have survived in any of the present continental waters; and it is equally remarkable that no evidence of its former existence in North America has been discovered except that which the Puget fauna has furnished. If the dispersion of Batissa was toward this continent, it seems to have only reached the present Pacific coast region about the close of the Cretaceous period, and to have there and then become extinct; while it has continued its existence on certain islands of the Pacific to the present time. But all the known facts concerning the genus Batissa are insufficient to throw much light upon its geological history or geographical dispersion. Even the Corbiculidæ, the family to which Batissa belongs has a less completely known geological history in North America than has the Unionidæ.

Art. XLV.—*Two Sulphantimonites from Colorado;* by L. G. Eakins.*

The mineral first to be described was sent to the Denver laboratory of the U. S. Geological Survey in the latter part of 1885, by Mr. E. R. Warren, of Crested Butte, Colorado.

At that time a hasty qualitative examination was made, establishing the fact that it was a sulphantimonite of lead, and since then nothing more has been done with it until the present analysis was made.

* Read before the Colorado Scientific Society, Meeting of June, 1888.

This mineral comes from the "Domingo" Mine, on the ridge between Dark Cañon and Baxter Basin, Gunnison Co., Col.; in which locality it is known as "mineral wool." It consists of aggregates of small acicular crystals, forming matted, wool-like masses in the cavities of a highly decomposed gangue rock of siliceous material mixed with some calcite. It is dull, grayish black in color, with occasional spots of iridescence, due undoubtedly to a slight superficial oxidation.

In procuring material for analysis, a lot of loose material sent by Mr. Warren was slightly crushed and rubbed with water in a mortar and poured off, the fine needle-like crystals floating off readily; this was afterward purified by a re-treatment in the same manner, and then subjected for a short time to the action of dilute hydrochloric acid to remove the slight amount of attached calcite. The material obtained in this manner appeared under the microscope to be perfectly pure and homogeneous with the exception of a slight amount of gangue still remaining.

No crystalline form could be made out, and on account of its peculiar nature no attempt has been made to determine either specific gravity or hardness. Heated before the blowpipe it fuses readily without decrepitation; in the closed tube it gives a slight sublimate of sulphur only; in the open tube it gives off sulphurous acid and dense white fumes of oxide of antimony; heated strongly the antimony all volatilizes, leaving a fused residue of sulphate of lead, slightly colored by the iron present; on charcoal it gives the lead and antimony coatings, and in the reducing flame with soda, a lead button. It is soluble in hot, strong hydrochloric acid with evolution of hydrogen sulphide.

The analysis is as follows:

		Atomic ratios.	
Ag	trace		
Cu	trace		
Pb	39·33	÷207=·190	·222
Fe	1·77	÷ 56=·032	
Mn	trace		
Sb	36·34	÷120=	·303
S	21·19	÷321=	·662
Insoluble gangue,	·52		
	99·15		

Dividing these atomic ratios by ·222, we get:—

Pb, Fe,	= 1	= 3
Sb,	1·36	4·08
S,	2·98	8·94

Giving the formula:—$(Pb, Fe)_3Sb_4S_9$, or $3(Pb, Fe)S, 2Sb_2S_3$.

This mineral, it is seen, fills a place in the group—3RS, 2(As, Bi, Sb)$_2$S$_3$, of which there are but few good examples, and which until now has not had an antimony representative.

The somewhat low summation of the analysis is probably due to two causes; first, a small amount of soluble gangue which was present and undetermined; second, the sulphur is about four-tenths of one per cent less than required, due to the slight natural oxidation of the mineral together with an additional amount induced by treatment with dilute hydrochloric acid for the removal of calcite. In addition to the complete analysis given, there were additional determinations made of lead, antimony and sulphur, the results obtained being in strict agreement with those given above.

The second of these sulphantimonites was collected in the summer of 1887, by Mr. Whitman Cross; it comes from a mine on Augusta Mountain, Gunnison Co., Col., this locality being about one mile east of the "Domingo" mine.

Locally this mineral is also known as "mineral wool," and although differing considerably in appearance from the one just described, they were, on account of the similarity of occurrence, considered as probably identical.

It occurs in a siliceous gangue together with pyrite and sphalerite, and forms groups of acicular crystals which are elongated prisms, deeply striated; but whose form could not be determined.

The individual crystals of this mineral are considerably larger than those of the one previously described, and in consequence they do not tend so much to form matted aggregates. Its color is a bright, steely, grayish black, with no tendency toward tarnish or iridescence. The separation of this mineral from the accompanying ones and the gangue, was a matter of considerable difficulty; on account of their size the crystals could not be successfully washed out from the other material, but by the use of a rapid current of water, and the Thoulet method, a small quantity was finally procured perfectly free from everything except some pyrite, and that had no effect upon the analysis, as the mineral was dissolved in a mixture of hydrochloric and tartaric acids, leaving the pyrite unattacked; it was then filtered through a Gooch crucible, and the amount of pyrite determined and deducted from the material taken. The fact that but a trace of iron was found in the analysis is conclusive proof that the pyrite was practically unattacked.

Blowpipe characteristics are the same as in the one before described.

The analysis is as follows:

		Atomic ratios.
Ag	trace	
Pb	55·52	÷207=·268
Fe	trace	
Sb	25·99	÷120=·217
(calculated) S,	18·98	÷ 32=·593
	100·49	

Dividing these atomic ratios by ·217 we get:

Pb,	= 1·24	= 4·96
Sb,	1	4
S,	2·74	10·96

Giving the formula:—$Pb_5Sb_4S_{11}$ or $5PbS, 2Sb_2S_3$.

We have here, in formula, a freieslebenite in which instead of lead and silver, the silver has been completely replaced by lead, and although the crystallographic agreement of this mineral with freieslebenite has not been established, there seems to be no good reason for not referring it to that species.

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Art. XLVI.—*On the Voltametric Measurement of Alternating Currents*; by A. E. Kennelly.

It has until quite recently been generally supposed that an electric current reversing its direction with the frequency that characterizes what is commonly called an alternating current, would not decompose water visibly, or in fact that if any decomposition did take place at the electrodes, the recombination at the reversal was so speedy and complete that no free gas was developed. It has been shown, however, lately, in a paper by MM. Maneuvrier and Chappuis, read before the Académie des Sciences, that when the electrodes are small, free decomposition does take place, mixed gas being liberated at each. Since that time Professors Ayrton and Perry have contributed to the data on the subject in an article appearing in "The Electrician" of London, July 13, 1888, and in which some very interesting phenomena observed with polarized electrodes are described, while it is mentioned that the quantity of gas liberated under given conditions is a function not only of the current density per unit surface of electrode but also of the rate of alternation.

No statement of the connection that exists between these variables seems to have yet been published. The following experiments made recently at Mr. T. A. Edison's laboratory

for the purpose of investigating this matter show that under certain conditions the quantity of gas liberated is in very close accordance with that which a continuous current of equal strength would supply, and hence afford ground for the hope that it will shortly be possible to measure the strengths of alternating currents by the voltameter as closely and as conveniently as in the case of continuous currents.

Two methods have been tried. (1) The condenser method or incomplete metallic circuit. (2) The ordinary method with complete metallic-and-liquid circuit.

Several series of measurements have been made, all agreeing very fairly. The following series taken at one time will suffice for all.

The source of the alternating current was a Siemen's alternating dynamo machine designed for 100 volts, the electromotive force being readily under control through the current in its field magnets; the speed of revolution on the occasion of this experiment was steady at 1470 per minute. At this speed its alternations, being 8 to the revolution, are 196 per second.

The voltameter was of special construction. An ordinary glass evaporating dish $11{\cdot}5^{cms}$ in diameter and 6·3 high was filled about two-thirds with a 10 per cent (by weight) solution of pure sulphuric acid in distilled water, the density of this solution being 1·065 at 19° C. At the bottom of the dish was immersed a disk of resinous material 5^{cms} in diameter and $1{\cdot}2^{cms}$ high. Twelve platinum wires of different lengths but equal

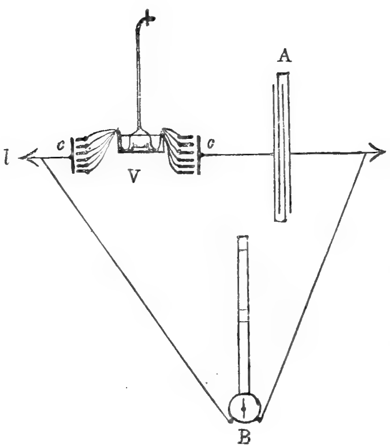
Nos. of couple.	Diameter, cms.	Circumference, cms.	Length of each wire, cms.	Cylinder surface, sq. cms.	Section surface, sq. cms.	Total surface of each plate, sq. cms.	Sum of surfaces in multiple.	Great'st h'rizont'l distance betw'n wires forming couple.	Least horizontal distance.
1	0·0178	0·0559	1·5	$8{\cdot}39\times10^{-2}$	$0{\cdot}025\times10^{-2}$	$8{\cdot}415\times10^{-2}$	$21{\cdot}555\times10^{-2}$		
2	"	"	1·0	$5{\cdot}59\times10^{-2}$	"	$5{\cdot}62\times10^{-2}$	$13{\cdot}140\times10^{-2}$	$3{\cdot}7^{cm}$	1^{cm}
3	"	"	0·8	$4{\cdot}47\times10^{-2}$	"	$4{\cdot}50\times10^{-2}$	$7{\cdot}520\times10^{-2}$		
4	"	"	0·4	$2{\cdot}24\times10^{-2}$	"	$2{\cdot}27\times10^{-2}$	$3{\cdot}020\times10^{-2}$		
5	"	"	0·1	$0{\cdot}56\times10^{-2}$	"	$0{\cdot}585\times10^{-2}$	$0{\cdot}750\times10^{-2}$		
6	"	"	0·025	$0{\cdot}14\times10^{-2}$	"	$0{\cdot}165\times10^{-2}$	$0{\cdot}165\times10^{-2}$		

diameter ($0{\cdot}0178^{cms}$) projected vertically from the upper surface of the disk, so as to stand in a ring of 4^{cms} diameter and equidistant from each other. These wires were ranged from $1{\cdot}5^{cms}$ down to $0{\cdot}025^{cms}$ in length, the corresponding wires across one diameter having as closely as possible equal lengths. Connections with rubber-covered wires sealed in the material of the

disk made six little separate voltameters each with its own pair of insulated leads. By uniting more or less of these leads outside the dish, the voltameter might be made to comprise any or all of the couples of electrodes, thus enabling a considerable range of electrode area to be at command as shown by the preceding table.

Over this sextuple voltameter there rested a glass bell 7^{cms} in diameter, terminating after 10^{cms} of elevation in a vertical glass tube of uniform bore $37{\cdot}5^{cms}$ long and about $0{\cdot}6^{cms}$ internal diameter, closed at the top by a rubber tube and clamp. This tube was graduated for volume by comparison with a burette and found to have a capacity per linear centimeter from several measurements of $0{\cdot}2684 \pm 0{\cdot}002$ c. c. In using the instrument, the tube and bell were filled with solution and gas electrolytically generated until the latter stood at a certain mark near the top. All being ready, the measured current was then passed through the apparatus for a noted interval, at the end of which the length of tube occupied by gas was measured downward from the fiducial mark.

1.



In the condenser method the connections were as shown in the diagram: where A is the adjustable condenser, V the voltameter with commutators *c c* for connecting the separate couples of plates in multiple, B a Cardew voltmeter, and *l l* the leads to the dynamo.

Under these conditions we know that the absolute quantity of current passing through the voltameter assuming that the periodic variation of electromotive force follows the sine law:

$$Q = n \pi e k t \times 10^{-7} \qquad (1)$$

where Q is the absolute quantity of electricity that traverses the voltameter in time t; e is the mean alternating potential difference as indicated by the Cardew voltmeter B; k is the capacity of the condenser A in microfarads; and n is the number of alternations per second. This formula is thus independent of the resistance of the voltameter, which is quite negligible under these conditions. If V_0 be the volume of gas at zero Centigrade theoretically decomposed by a continuous cur-

No. of trial.	Sept. 15. Time of passage of current.	Seconds elapsi'g. t.	Voltameter couples in circuit.	Area of each compound electrode. sq. c.	Capacity K inserted in A.	Cardew reading.	Corresponding mean altg. voltage. volts.	Length of tube filled by gas. cms.	Corresponding volume. c. c.	Equivalent current c. abs. units.	Calculated volume V_0. c. c.	Volume corrected to temp. 19° C. c. c.	Ratio of observed vol. / Calculated vol.	Density of current per cm. of electrode. abs. units.
1	17 13·00/21·20	500	1, 2, 3, 4, 5, 6	$21·56 \times 10^{-2}$	4φ	87° 45′	97·3	5·15	1·383	$2·4 \times 10^{-2}$	20·87	22·32	0·062	0·112
2	17 31·00/36·00	300	4, 5, 6	$3·02 \times 10^{-2}$	4	87°	96·8	18·7	5·02	$2·39 \times 10^{-2}$	12·37	13·23	0·380	0.79
3	17 40·00/44·00	240	5 and 6	$0·75 \times 10^{-2}$	4	85° 30′	95·7	30·55	8·20	$2·36 \times 10^{-2}$	9·78	10·46	0·784	3·15
4	17 53·00/55·00	120	6	$0·165 \times 10^{-2}$	2	82°	93·1	9·3	2·50	$1·15 \times 10^{-2}$	2·38	2·55	0·980	6·97
5	17·57·00/18·00·00	180	6	$0·165 \times 10^{-2}$	4	84° 20′	94·8	27·7	7 44	$2·34 \times 10^{-2}$	7·27	7·78	0·956	14·18
6	21·20·06		6	$0·165 \times 10^{-2}$	4	83°	93·9	On mak	ing conta	ct one of	the elec	trodes o	f couple	No.6 burned.
7	21·32·00/35·00	180	one of 5 and opposite of 6.	$0·585 \times 10^{-2}$ / $0·165 \times 10^{-2}$	4	85° 15′	95·4	27·75	7·45	$2·35 \times 10^{-2}$	7·31	7·82	0·953	Av'ge=6·26
8	21 39·00/42·00	180	do.	do.	2	81°	92·4	11·65	3·13	$1·14 \times 10^{-2}$	3·54	3·78	0·826	Av'ge=3·04
9	21 46·00/49·00	180	do.	do.	3	82°	93·1	19·05	5·11	$1·73 \times 10^{-2}$	5·35	5·72	0·893	Av'ge=4·61
10	21·57·00		do.	do.	5	80°	91·9	On mak	ing conta	ct the oth	er elec	trode of	No. 6	burned.
11	22·01·00/03·00	120	5	$0·585 \times 10^{-2}$	5	85°	95·3	24·5	6·57	$2·93 \times 10^{-2}$	6·09	6 51	1·009	5·01
12	22·06·00/08·00	120	5	$0·585 \times 10^{-2}$	5	85° 15′	95·4	24·5	6·57	$2·94 \times 10^{-2}$	6·11	6·53	1·006	5·01
					Resistance inserted in place of A.									
13	22 17·00/27·00	600	5	$0·585 \times 10^{-2}$	720ω	80° 20′	92·1	26·25	7·04	$1·22 \times 10^{-2}$	12·65	13·53	0·520	2·09
14	22·44·30/46·45	135	5	$0·585 \times 10^{-2}$	A lamp offering 230ω	78° 00′	90·4	30·80	8·26	$3·47 \times 10^{-2}$	8·09	8·65	0·955	5.93
15	22 48·45/51·00	135	5	$0·585 \times 10^{-2}$	do.	78° 00′	90·4	30·65	8·22	$3·47 \times 10^{-2}$	8·09	8·65	0·950	5·93

rent c in absolute measure equivalent to the passage of this quantity Q, we have

$$c = n \pi e k \times 10^{-7} \tag{2}$$

$$\text{and } V_0 = 5{\cdot}43\, n e k t \times 10^{-7} \tag{3}$$

Besides the Cardew voltmeter steady potential indication, a quadrant electrometer, not shown in the diagram, with its needle connected to one pair of quadrants, was employed to measure the potential difference at the voltameter terminals and thus indicate its mean resistance.

The preceding table gives the results of 10 measurements. The volume of the gas is corrected for temperature, but no correction is introduced for the barometric pressure or the tension sustained by the gas in the tube.

The condenser used was adjustable from 0·001 up to 5 microfarads, and from absolute determinations is probably accurate to at least 0·5 per cent.

The last two columns show that

When the density of current per sq. cm. of either electrode was:	the percentage of gas actually generated of that calculated as due was:
1·12	6·2 per cent.
7·9	38 "
30·4 (average)	82·6 "
31·5	78·4 "
46·1 (average)	89·3 "
50·1	100·8 "
62·6 (average)	95·3 "
69·7	98·0 "
141·8	95·6 "

The trials Nos. 13, 14 and 15 were taken without condenser, and with non-inductant resistances in its place. In trial No. 13 this resistance was a length of fine platinum wire offering 720 ohms (hot). In trial Nos. 14 and 15 the resistance was a 96 volt 10 candle-power Edison lamp offering 230 ohms resistance at equivalent illumination. In calculating the current strengths for these three observations, the resistance of the voltameter itself was required. It was measured in two ways: 1st, by means of the quadrant electrometer and the potential differences it indicated on the known resistance and on the voltameter; 2d, by rapidly substituting a non inductant resistance alternately with the voltameter in the lamp circuit and adjusting this resistance until the illumination was equal in both cases. These two methods concurred in showing the resistance of the voltameter to be 30 ohms, and the maximum resistance it offered through the whole series was 35 ohms.

The table shows that

When the current density per sq. cm. of either electrode was:	The per centage of calculated gas actually liberated was:
20·9	52
59·3	95·3

These results, corroborated by several previous series, go to show that for a rate of alternation of 200 per second and currents of between 0·1 and 0·35 ampères the quantity of gas generated by an alternating current in a voltameter is approximately equal to that generated by an equal continuous current when the mean current density at the surface of the electrode is above 50 ampères per sq. cm. of each; that below that density the quantity of gas developed rapidly diminishes, and that below 1 ampère per sq. cm. soon disappears.

Also that the resistance of a voltameter with very small plates traversed by an alternating current is much less than that it would offer to an equal continuous current. Were this not the case, the resistance of a voltameter for alternating current measurements might for many purposes prove prohibitively great.

ART. XLVII.—*Remarks on the Fauna of the Great Smoky Mountains; with Description of a new species of Red-backed Mouse (Evotomys Carolinensis)*; by DR. C. HART MERRIAM.

THE fauna of the higher portions of the southern Alleghanies remained almost unknown until 1870, when Prof. E. D. Cope published a paper on the subject.* His bird notes were made so late in the season (in August and September) as to include the beginning of the fall migration and hence are without value so far as concerns the faunal position of the region. Among mammals, he recorded the Red Squirrel and Canada Lynx as inhabiting the higher mountains. A single species of Salamander, the northern *Desmognathus ochrophæus*, was found on the high peaks of the Black Mountains.

The botany of the region received considerable attention, but sixteen years passed after the appearance of Prof. Cope's paper before anything of importance was contributed to our knowledge of its vertebrate fauna. In 1886 Mr. William Brewster published the results of a very brief visit, made at the beginning of the breeding season of birds, to the mountains of western North Carolina (The Auk, iii, 1886, 94-112; 173-179).

* Observations on the Fauna of the Southern Alleghanies. Am. Nat. iv, 1870, pp. 392-402.

On the higher summits Mr. Brewster found breeding in abundance such northern birds as the Winter Wren, Golden-crested Kinglet, Red-bellied Nuthatch, Junco, Solitary Vireo, Olive-sided Flycatcher, Red Crossbill, Pine Linnet, Black-throated Blue Warbler, Blackburnian Warbler, Canada Flycatching Warbler, and several others. He found the region separable into the Canadian, Alleghanian, and Carolinian Faunæ, concerning which he says: "The boundaries of these divisions are determined chiefly by elevation, the Canadian occupying the tops and upper slopes of the higher mountains down to about 4500 feet, the Alleghanian, the mountain sides, higher valleys, and plateaus between 4500 and 2500 feet, and the Carolinian everything below the altitude last named."

Two of the Canadian birds, namely the Junco and the Blue-headed Vireo, were found to be distinguishable from their northern representatives, and hence were subspecifically separated under the names *Junco hyemalis Carolinensis* and *Vireo solitarius alticola*, respectively.

During the summer of 1887 it was my good fortune to visit this very interesting region, in company with Mr. Henry Gannett, Chief Geographer of the U. S. Geological Survey. By Mr. Gannett's kindness I was enabled to accompany him during a buckboard drive of several hundred miles through the Great Smoky Mountains of Tennessee and North Carolina. Although we entered the mountains in the last week of July, migration had already begun, and it was impossible in most cases to discriminate between the resident and migrant birds. In the case of the Junco, however, young were found in all stages of development from the newly hatched nestling to the fully adult bird; and the important fact was ascertained that the local form inhabiting these mountains is specifically distinct from its northern congener. Hence it must stand as *Junco Carolinensis* Brewster.

Of mammals, the Black Bear, Wolf, Deer, Wild Cat, both Red and Gray Foxes, Raccoon, Opossum, and Gray Squirrel still occur in greater or less abundance according to the locality and altitude. The Panther, Porcupine, Pekan, and Varying Hare are unknown. The Chipmunk (*Tamias striatus*) and Woodchuck or Ground Hog (*Arctomys monax*) were common in places in the Alleghanian belt, about half way up the mountains; and the Gray Rabbit (*Lepus sylvaticus*), Red Squirrel (*Sciurus Hudsonius*), and a Red-backed Mouse (*Evotomys*), were common on the higher summits. The latter genus is circumpolar in distribution and has not been previously recorded from any locality south of Massachusetts The present representative of the genus is about double the size of the Canadian *Evotomys Gapperi*, and proves to be distinct from any previously described species. It may be characterized as follows:

Evotomys Carolinensis, sp. nov.

Type 3660, ♀ adult, Merriam Collection. From Roan Mountain, North Carolina (altitude 6000 feet), August 11, 1887. C. H. M.

Description of type.—Size much larger than that of any other known representative of the genus. The following measurements were taken in the flesh: total length 164^{mm}; head and body 111^{mm}; nose to eye 13^{mm}; to center of pupil 15^{mm}; nose to occiput 29^{mm}; tail vertebræ 44^{mm}; pencil 7^{mm}; fore foot 13^{mm}; hind foot 21^{mm}; fore leg 26^{mm}; hind leg 37^{mm}; height of ear from crown 11^{mm}; distance between eyes 9^{mm}; Ears large, suborbicular, prominent; superior margin much incurved but not inflexed; superior root considerably anterior to plane of meatus; antitragus large, its anterior root curving upward in front of meatus and almost reaching the superior root of the auricle. Tail long and slender, tapering from base to tip; not sharply bicolor, though paler below than above. Whiskers black and white, reaching little beyond tips of ears. Hind feet very large, and as broad as in Arctic *rutilus*, though by no means so densely haired; dark, with whitish hairs about the nails; posterior third of soles well haired.

Upper parts dark, with a liberal admixture of black-tipped hairs (agreeing in this respect with specimens of *E. Gapperi* from the upper Red River Valley); dorsal stripe dull chestnut and very broad, spreading out laterally and almost fading insensibly into the fulvous suffusion of the sides (in all the other known forms the dorsal stripe is sharply defined laterally). Sides bister, strongly suffused with light fulvous all the way from the cheeks to the thighs. Color of sides reaching down so far as to seem to encroach on the whitish of the belly, completely enveloping the legs. The belly is strongly washed with ochraceous.

Description of other specimens.—A number of specimens from Highlands, N. C., collected in February, March, and April, agree with the above in all essential respects. The line separating the color of the sides from that of the belly is always distinct and sometimes sharply defined (as in Nos. 2057 ♀, and 2314 ♂). The plumbeous basal portion of the fur shows through on the throat but not on the belly, where it is usually entirely obscured by the whitish apical portion. The ochraceous wash is strongest on the middle of the belly. The tail varies in length in the dry skins from 44^{mm} to 58^{mm}, but these measurements must be regarded as approximate only, owing to possible distortion in preparing the specimens. It is always bicolor with a distinct line of demarcation, though the under surface is never white. The average length of the hind foot in six dry skins is $19{\cdot}5^{mm}$.

ART. XLVIII.—*On a new Thorium Mineral, Auerlite;* by W. E. HIDDEN and J. B. MACKINTOSH.

WHILE one of us was about completing a contract for twenty-six tons of zircons, to supply a recent large demand for that mineral, several crystals of the mineral forming the subject of this paper were noticed in the very last shipments from the mine. As the quantity then found was insufficient for a complete chemical and physical examination, the locality was revisited in July last and for five weeks a systematic and laborious search for the mineral *in situ* was carried on. We had already proved it to be a hydrous mineral rich in thoria, with silica and, strangely, a very appreciable quantity of phosphoric acid. Our interest was centered upon its apparent anomalous composition and a series of careful analyses was made by one of us as soon as the necessary material was procured. As the result of the search at the locality not quite 100 grams were found and it became necessary to mine over 200 kilos of zircons to get even this small amount.

It has thus far been found at only two places in Henderson County, North Carolina, namely, at the well-known Freeman mine, on Green River, and on the Price land, three miles southwesterly. At both places it occurs in disintegrated granitic and gneissic rocks intimately associated with crystals of zircons, and it is often seen implanted upon them—as a second or after-growth—in parallel position.

The color on a fractured surface ranges in different crystals from a pale lemon-yellow through various shades of orange to a deep brown-red. The form is distinctly tetragonal, only the unit pyramid and prism being observed, and excepting a tendency to a longer prismatic development, it is much like the common type of zircon found throughout the region. The faces being very rough and uneven, no constant angles could be obtained on any of the material, but they closely approximate to those of zircon.

Fragments of the mineral resemble some varieties of gummite and deweylite, but have a more waxy or rosin like appearance. It is sub-translucent to opaque, and has a dull yellowish white exterior. It is very brittle and easily crumbled. The hardness varies from 2·5 to 3, some crystals barely scratching cleavage surfaces of calcite. The specific gravity has a wide range, i. e. from 4·422 to 4·766, the dark-orange-red crystals having the highest density.*

* Some of the crystals were much lighter in color, softer and of specific gravity from 3·7 to 3·8. These we propose to examine and report upon later.

The largest mass found measured 1^{cm} through the prism, and it was evidently only part of what had been a long crystal. The bulk of what we collected is in a very fragmentary condition, down to masses and broken crystals of 1^{mm} diameter.

Our analyses have given the following results:

	1.	2.	3.	4.	5.
H_2O	10·7	----	11·21	----	9·88
CO_2				----	1·00
SiO_2	----	9·25	7·64	8·25	
P_2O_5	----	----	7·46	7·59	
ThO_2	----	69·23	70·13		
Fe_2O_3	----	1·42	1·38		
CaO	----	----	0·49		
MgO	----	----	0·29		
Al_2O_3, etc.*	----	----	1·10		
			99·70		

If the amount of CO_2 in analysis number 3 is assumed to be the same as it is in 5, and if we take the amount of H_2O as the difference between the loss on ignition and the CO_2, the ratio of hydrogen equivalents, of bases and acids (assuming the carbonates to be admixed impurity), is nearly 2 : 1 : 2. This gives the formula,

$$ThO_2, \left\{ \begin{matrix} SiO_2 \\ \frac{1}{3}P_2O_5 \end{matrix} \right\} 2H_2O,$$

or a thorite in which part of the silica is replaced by its equivalent in phosphoric acid, when $3SiO_2 = 1P_2O_5$. The ratio of silica to phosphoric acid is variable and is approximately 1 : 1 in hydrogen equivalents; but the P_2O_5 tends to be in excess.

We have considered it possible that this mineral is a mixture of a hydrated thorium phosphate with a hydrated thorium silicate, in some respects analogous to the occurrence of zirconium-silicate (zircon) in parallel position with yttrium-phosphate (xenotime),† although there is nothing in the appearance to suggest this—the mineral seeming to be perfectly homogeneous, except on the exposed surfaces. It is more probable, however, that we have here an example of a partial replacement of silica by phosphoric acid, which fact has not yet, to our knowledge, been noticed in the literature of Mineralogy; unless we should so regard the small proportion of P_2O_5 (4·17) which Eakins‡ observed in the xanthitane (altered titanite) from the same locality.

This occurrence of a thorium phosphate is the first instance of such a compound existing in nature and seems to have a

* Including other oxides with traces of thoria.

† This Journal, Nov., 1888, p. 380.

‡ This Journal, vol. xxxv, p. 418, May, 1888.

direct bearing upon the presence of thorium in monazite, and we believe that the idea that thorium is included in monazite as thorite—mechanically intermixed—should be modified in so much that the thoria should be considered as partially present as a phosphate and the cerium earths partially present as silicates.

This mineral is readily soluble in hydrochloric acid, leaving a residue of gelatinous silica; after ignition it becomes insoluble. Thorium phosphate is generally regarded as a very insoluble compound, but the ready solubility of this mineral seems to disprove that opinion.

It is infusible and upon strong ignition becomes dull-brown and on cooling, orange again.

Thorite crystals having the form of zircon have been described by Zschau;* and Nordenskiöld,† and later Brögger,‡ have expressed the opinion that the mineral known as thorite is a pseudomorph after an original thorium silicate analogous to zircon in composition. This view is confirmed by the fact that this new mineral occurs intimately associated with and implanted upon perfectly unaltered zircon.

As this mineral was found while mining the very large quantity of zircons necessary to supply the demand caused by the invention of the system of incandescent gas-lighting of Dr. Carl Auer von Welsbach, we propose to name it *Auerlite* in his honor.

Art. XLIX.—*On a new Sodium sulphato-chloride, Sulphohalite;* by W. E. Hidden and J. B. Mackintosh.

It was in the mineral collection of Mr. Clarence S. Bement, of Philadelphia, and along with a series of remarkable crystals of hanksite that one of us first noticed the mineral here described; it was recognized by a few simple tests to be a new species. It had been considered, at the locality, to be "a rhombohedral type of hanksite" and the misinterpreted form of its crystals —implanted as they were upon hanksite—was the reason for that opinion. A few measurements with a hand goniometer soon showed them to belong to the isometric system and the form to be the simple rhombic dodecahedron. The mineral occurs only as crystals, which are in form and sharpness of angle, all that could be desired. It is transparent with a faint greenish-yellow color. The crystal faces are smooth and well polished and vary in size from $\frac{1}{2}$ to $2\frac{1}{2}^{cm}$ diameter. The spe-

* This Journal, II, xxvi, 359; see also Dana's Syst. Min., Ed. 1868, p. 413.
† Geol. För. Förh., iii, 226, 1876; see also App. III, Dana's Min., p. 121.
‡ Ibid, ix, 258, 1887.

cific gravity, as taken in naphtha, is 2·489. Their hardness is about 3·5. The mineral is very slowly soluble in water and remains unaltered in a moderately dry atmosphere. A careful analysis by one of us on amounts of 100 and 120 milligrams yielded the following results:—

Cl	13·12	per cent.
SO_3	42·484	"
Na_2CO_3	1·77	"

Calculating the chlorine and sulphur as combined with sodium only, we get

$NaCl_2$	21·624
Na_2SO_4	75·411
Na_2CO_3	1·77
	98·805

The formula figures out exactly, if the loss and the Na_2CO_3 are estimated with and as Na_2SO_4; i. e., if the loss is Na_2SO_4 and we consider the Na_2CO_3 as replacing a little Na_3SO_4.

The formula can then be expressed thus: $Na_2(\frac{3}{4}SO_4, \frac{1}{4}Cl_2)$ or $3Na_2SO_4 . 2NaCl$. Excepting the very rare mineral connellite, from Cornwall, England, which is believed to be a cupreous sulphato-chloride (crystallizing in the hexagonal system), we know of no other species related in composition.

We learn from Dr. A. E. Foote, in whose stock of Borax Lake minerals we were fortunate enough to find the single specimen of the mineral used in this examination—that he had visited the locality this past summer and that about one month before his arrival a company had been testing the immense alkaline deposit of Borax Lake (San Bernardino County, California), and had drilled an eight inch hole to a depth of over 100 feet. At a depth of 35 feet a small cavity was discovered from which there were pumped out through the drill hole the mineral here announced, with some very remarkable crystals of hanksite.

But three examples are at present known to us, and two of these of remarkable beauty, are in the Bement collection, the other specimen (a crystal about one inch thick, having long prismatic hanksites implanted upon it), is the one, upon a part of which, this analysis was made.

It is a matter of interest to note that this mineral, with its anomalous formula, should occur with and be associated upon another mineral, hanksite, having a like strange composition.

We propose for this new mineral the name *sulphohalite* as suggesting its remarkable composition.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Vapor-density of Aluminum chloride.*—The experiments of Nilson and Pettersson (Zeitschr. phys. Chem., i, 459) seemed to show that aluminum chloride when heated in an atmosphere of carbon dioxide gave, at a temperature of about 835°, a vapor-density corresponding to the formula $AlCl_3$; and this without evidence of decomposition, although above 935° the platinum vessel was attacked. Friedel and Crafts have pointed out that exact results are obtained with V. Meyer's method (which was the one used by Nilson and Pettersson) only when there is no diffusion of the vapor into the air of the apparatus. And they have therefore re-determined the vapor-density of aluminum chloride by the method of Dumas, taking great care to obtain and to maintain the substance perfectly anhydrous. The aluminum chloride was obtained by sublimation in large, colorless and comparatively non-hygroscopic crystals, which though volatilizing directly without fusion at ordinary pressures, melt at about 186° under a pressure of 2·5 atmospheres. The vapor-pressure of this substance was found to be 252·1 mm. at 167·8°; 311·4 mm. at 170·4°; 316·5 mm. at 171·9°; 430·7 mm. at 175·7°; 755·4 mm. at 182·7°; 1793·4 mm. at 204·2°; 2016·1 at 207·5°; and 2277·5 mm. at 213·0°. The temperatures at which the vapor-densities were determined were 218°, 263°, 306°, 357°, 390°, 398°, 400°, 415°, 429° and 433°; and the results agreed closely with the density 9·24, the value corresponding to the formula Al_2Cl_6; thus confirming the earlier results of Deville and Troost. Since the lowest temperature at which Nilson and Pettersson operated was 440°, it may be that the lower values obtained by them are due to a dissociation of the molecule Al_2Cl_6 into $(AlCl_3)_2$ analogous to that of iodine, or into Al_2Cl_4 and Cl_2 as in the case of ferric chloride. The authors' experiments prove, however, that aluminum chloride becomes a perfect gas at 218°, or 35 degrees above its boiling point; and that the density of this vapor is sensibly the same up to 400°. Hence they conclude that the formula of this substance is Al_2Cl_6; a conclusion in agreement with the determinations of Louise and de Roux of the vapor-densities of aluminum methide and aluminum ethide.—*C. R.*, cvi, 1764; *J. Chem. Soc.*, liv, 1040, Oct., 1888. G. F. B.

2. *On Freezing mixtures containing solid Carbon dioxide.*—Cailletet and Colardeau have determined the temperature of solid carbon dioxide, alone as well as when mixed with other suitable substances, in air and in vacuo. For this purpose they used a thermo-electric couple which had been calibrated by comparison with a hydrogen thermometer. The carbon dioxide alone, either compressed or porous, when exposed to the air, had a temperature −60° and when in a vacuum over potassium hydrate,

—76°. When mixed with ether, the dioxide had a temperature of —77° in air and of —103° in a vacuum. Liquid carbon dioxide solidifies in such a mixture. On the addition of the solid dioxide to the ether it at first dissolves, and after a time bubbles of gas are evolved. On continuing to add the dioxide the liquid becomes saturated and opalescent, the temperature falling until the instant of saturation is reached, when no farther fall of temperature occurs on adding more dioxide. Hence it would appear that the effect of the ether is due simply to its dissolving the dioxide. Other solvents may be used. Methyl chloride gives —82°; sulphurous oxide —82°; amyl acetate —78°; phosphorous chloride —76°; alcohol —72°; and ethylene chloride —60°. When the mixture with methyl chloride or sulphurous oxide is placed in a vacuum the temperature is lowered to a point at which the solvent solidifies and then no farther reduction takes place. The temperature thus obtained with methyl chloride is —106°. A mixture with chloroform solidified at the ordinary pressure at —77°.—*C. R.*, cvi, 1631; *J. Chem. Soc.*, liv, 1025, Oct., 1888. G. F. B.

3. *On the Determination of the Heat of Combustion of Coal.*—SCHEURER-KESTNER has analyzed and has also determined the heat of combustion of twenty-one samples of coal from the north of France, by direct experiment, and has compared the results with those calculated from the composition of the coals. The coal in small fragments was burned in a rapid current of moist oxygen in a Favre and Silbermann's calorimeter; the results being corrected by subtracting from the heat of combustion actually observed with the moist gas, and consequently with complete condensation of the water formed, the number of calories equivalent to this condensation. Since the combustion of hydrogen gives 34,500 or 29,088 calories according as the water formed is condensed or is in the state of vapor, the difference, or 5413 calories, multiplied by the content of the coal in hydrogen, represents the number of calories to be subtracted from the observed heat of combustion. The values of the heats of combustion actually obtained do not agree with the values calculated from the composition, being sometimes greater than the sum of the heats of combustion of the constituents and sometimes less. Cornut has proposed a formula for calculation based on the assumption that while solid carbon evolves 8080 calories, the heat of combustion of carbon in the state of vapor is 11,214 calories. But the calculations founded on this formula of Cornut, while giving results somewhat closer to those actually observed in some cases, are in other cases so far from the truth as to destroy confidence in it. The formula of Dulong is even less satisfactory. No explanation is offered as to the cause of these discrepant results, but they seem to establish the important fact that coal has been formed at least in part by endothermic reactions. The general results give between 8340 and 9257 calories, the mean values lying between 8400 and 8800 calories.—*Ann. Chim. Phys.*, VI, xv, 262, Oct., 1888. *J. Chem. Soc.*, liv, 774, Aug., 1888. G. F. B.

4. *On the Wave-length of the Double red line in the spectrum of Potassium.*—By means of a Rutherfurd grating ruled on glass, and the electric arc, Deslandres has succeeded in measuring the wave-length of the two components of the double potassium line in the red, known as Kα. He finds for the stronger of the two lines the value 7663·0 ten-millionths of a millimeter, and for the weaker line the value 7696·3 ten-millionths; the value for D being taken at 5888·9. This agrees with the value 7680·0 found by Mascart for the group, that of D being 5888·0.—*C. R.*, cvi, 739; *J. Chem. Soc.*, liv, 637, July, 1888. G. F. B.

5. *Electrical discharges in gases and flames.*—The observation of Hertz upon the effect of the ultra violet rays upon electrical discharges has awakened wide spread interest in Germany. Among other workers, E. Wiedemann and H. Ebert have repeated and confirmed Hertz's results. They have also investigated the effect of ultra violet rays upon electrical discharges which are taken in various media. The source of light was a Schuckert's electric arc light. It was found that the effect of the ultra violet rays was greatest when the electrodes between which the electrical discharge passed were of platinum. A telephone was intercalated in the circuit and the character of the discharge when the electrodes were in the violet rays and when they were not could be readily distinguished. A glass plate which allowed the violet rays to pass, but absorbed the ultra violet, immediately caused the phenomenon to disappear; thus it was shown that the ultra violet rays alone were effective. The effect varied with the character of the electrodes, being greatest with platinum. And then in the following order: zinc, copper, iron, aluminum, palladium, silver. When the discharge was taken from the surface of a liquid, the greatest effect was always obtained when the liquid was capable of absorbing the ultra violet rays. The authors believe that the phenomena can be attributed to the selective absorption for ultra violet rays of the surfaces between which the electrical discharges pass. The short wave-lengths set the molecules on these surfaces into vibration and thus aid the disruptive effect which is seen in the discharge. The phenomenon was also investigated in Geissler tubes and with low pressures. When the electrical discharge grew rich in ultra violet rays, the effects of similiar rays from the arc lamp were less noticeable. The discharge was also taken between points placed in flames which were colored by various salts. These salts changed the character of the discharge greatly, as was evidenced by the noise in a telephone connected with one of the electrodes. The greatest effect was obtained from potash and from the magnesium salts, thus affording another instance of the effect of ultra violet rays affecting the electrodes by selective absorption.—*Ann. der Physik und Chemie*, No. 10, 1888, pp. 209–264. J. T.

6. *Electrodynamic effect produced by the movement of a dielectric in an electrical field.*—W. C. Röntgen revolved a glass or vulcanite disc between two horizontal plates of a condenser, one

of which was connected with the earth, the other with the source of electricity. Above the upper condenser plate was hung a very sensitive magnetic system. The direction of the magnetic needles was perpendicular to a radius of the revolving disc, and their middle point was near the edge of the disc. The deviation of this system was measured by a mirror, telescope and scale. The author concludes, after discussing the relation of the effects observed to those obtained by Rowland and by others, that a small electrodynamic effect can be noticed, when a dielectric is moved in a homogeneous electrical field.—*Ann. der Physik und Chemie,* No. 10, 1888, pp. 264–270. J. T.

7. *Light and Electricity.*—LORD RAYLEIGH (B. A., 1888) has been endeavoring to discover if an electric current flowing through an electrolyte causes the velocity of light to vary through the liquid. He experimented with dilute sulphuric acid. The result was negative within the range of the experiment, which was extremely delicate. In H_2SO_4 diluted, one ampère per square centimeter does not alter the velocity of light by one part in thirteen millions, or by fifteen meters per second.—*Nature,* Oct. 4, 1888, p. 555. J. T.

8. *The energy stored in permanent strains;* by C. BARUS. (Communicated). — Apropos of certain strain experiments of Wassmuth, an account of which has just reached me in the Beiblätter (No. 9, p. 648, 1888), I desire to advert to somewhat similar results which I have in hand. I brought a measured amount of work to bear on soft metallic wires, and by deducting from this the energy thermally dissipated (measured in a way essentially like that of Wassmuth), I was able to express definitely the energy potentialized in effecting given changes of molecular configuration. In this respect my work and purposes are distinct from Wassmuth's. Necessarily operating on *soft* metal, I find that the values for the maxima of energy stored under given conditions differ so largely in different metals, that I am justified in treating them as molecular data of importance.

II. GEOLOGY AND MINERALOGY.

1. *International Congress of Geology.*—The members of the "Provisional Committee" appointed at the Congress in London, with reference to preparations for the next meeting of the Congress at Philadelphia, whose names are mentioned on page 389, met at New Haven, on Thursday, the 15th of November. All were present except Dr. T. Sterry Hunt. By vote twenty-four members of the permanent or organizing committee were appointed, as follows: C. A. Ashburner, J. C. Branner, T. C. Chamberlin, G. H. Cook, J. D. Dana, W. M. Davis, C. E. Dutton, G. K. Gilbert, James Hall, A. Heilprin, C. H. Hitchcock, Joseph LeConte, J. Leidy, J. P. Lesley, O. C. Marsh, J. S. Newberry, J. W. Powell, J. R. Procter, N. S. Shaler, J. J. Stevenson, C. D. Walcott, R. P. Whitfield, H. S. Williams,

Alexander Winchell. The committee has power to add to its number. Dr. J. S. Newberry was appointed temporary chairman. With this action, the duties of the provisional committee ended. The first meeting of the permanent committee will be held in Washington in the month of April.

2. *American Report to the International Congress of Geologists at the meeting in London commencing September* 17, 1888.—This Report, as the title-page states, is made up of "Reports of the American Sub-committees appointed by the American Committee from its own members, assisted by associates, and is "printed by order of the Committee. Editor, Persifor Frazer." It contains valuable papers on American stratigraphical geology prepared chiefly by the Chairmen or "Reporters" of several Sub-committees, and interesting reading as the personal opinions on various questions, which were gathered in by the assiduous Secretary and some of the "Reporters" through epistolary canvassing. But on controverted points it is a "majority" report of the Committee and of its several Sub-committees, and a minority report as regards American geologists. The canvassing gathered opinions, but not the final views which free discussion among the geologists of the country would have evoked. Moreover the methods of the Committee tended to suppress discussion even in the Sub-committees.

The Preface of the published Report states that "all geologists were invited to meet the American Committee in Albany during its session there (April 6th, 1887), in order to aid it in arriving at a correct view of American opinion." Such a call was published in volume xxxiii of this Journal (1887); but the notice of the next meeting at Philadelphia, communicated to the same volume by the Secretary, shows that it failed of the object announced.

At the only meeting attended by the writer, that of January last at New Haven--not then *resuming* active membership, as the published Report states in its Preface, but taking my first experience in membership after receiving my first notice that I was a member, the chairman,—Dr. T. Sterry Hunt, opened the session in the morning by announcing that five-minute speeches only would be allowed in discussions, and no replies, thus showing at the outset that full and fair consideration of questions was not to be permitted.

During the day the reports of some of the Sub-committees were read and passed, but no opportunity was allowed for the discussion of any of the propositions to the International Congress which they contained. Before the meeting closed, a vote was passed by which "the *Reporters of the Sub-committees* respectively were made sole and final judges of the manner in which communications received from other geologists should be used." At the same time "the reports on the Archæan, Devonic, Carbonic, Mesozoic and marine Cenozoic" were declared adopted and ready for printing, and those "on the Lower Paleozoic and In-

terior Cenozoic were referred back to the Sub-committees making them," but not for any changes, except such as the "Reporters" might make. I was not aware in January that such votes had passed, nor that any of the reports were beyond amendment, and learned of it first through a letter from the Secretary in March. Major Powell addressed a communication on the subject, dated March 27th, to Professor Hall, protesting against such a ruling, and in opposition to other actions of the Committee, and at the same time resigned his connection with it. For like reasons, I did not attend the April meeting.

Finally, at the April meeting, it was voted that no copies of the published report should be delivered before September 17th, or in other words that the printed report with its final additions should be kept from the members of the Committee until the day of meeting of the Congress in London. And so it was: on the 17th, punctually, the first copies reached me in New Haven.

Under such partisan management, the conclusions in the printed reports of the several Sub-committees were not likely to represent fairly American geological opinions. It is true that in connection with each of them a large display is made of the names of the members of the Sub-committees, and of *all* of them in each case, as if they were alike responsible for the contents, and as if the members had met, at least once, and consulted together, read the last emendations and signed the document. But in this it gives a very wrong impression. My name is on two of the Sub-committees, but has no right to a place on either, although I gave assent to the request; for I was informed of no meeting of the Sub-committee for consultation, and joined in none, and gave my signature to nothing except the letters which I, like many others not of the Committees, wrote in answer to questions. In fact, as above shown, changes after the January meeting were made impossible except by the Reporter. I received a proof of the report on the Lower Paleozoic, but returned it without any words of approval and only a few on the Taconic question. Further, this report, as finally published, contains what was not in that proof; it is decidedly the report of the Reporter, who had been made the "final judge of the manner in which communications received should be used," not the Committee's report; and the same is true in some other cases. The views of Mr. C. D. Walcott are unfairly presented with great injustice to him, although he stands as an associate member of the Sub-committee, responsible as much as the rest for its Report.

Five hundred copies of the Report of the American Committee were published. It is now in the hands of the Secretary of the London meeting of the Congress, awaiting a second publication as if the expression of the views of the majority of American geologists. Its right to appear in the volume of Proceedings of the Congress for 1888 should be seriously considered if it is not already too late. J. D. D.

3. *On the Volcanic Phenomena of the Eruption of Krakatoa, and on the nature and distribution of the Volcanic Materials;* by J. W. Judd, F.R.S., Pres. Geol. Soc. 56 pp. 4to, with 6 plates. From the Report of the Royal Society Commission.—The great eruption of Krakatoa, its results, and the character of its ejected materials, are here ably discussed by Professor Judd, with illustrating plates, maps, and wood-cuts. After sketching the earlier history of the volcano, the author comes to the precursor events of the eruption of 1883, which began May 20th, and then to the culmination in the paroxysmal eruption of August 26th and 27th. Views and maps show the changes that took place at the time in the island and in the seas about it. The cone of Krakatoa was left between 2,000 and 3,000 feet high, and the crater more than 1,000 feet deep.

Professor Judd's explanation of the eruption is this: that the interruption of the regular escape of vapors and ejections that was consequent on the chilling of the surface of the liquid lava by inrushes of sea-water caused a check and then a rally of the pent-up force of gases seeking escape; that the catastrophic outburst was a direct consequence of this "check and rally" of the subterranean forces.

The rocks of the cone and the ejected materials are described in detail, and illustrated by microscopic sections. The rock about the crater is enstatite-dacite or enstatite-andesite. There are also black porphyritic pitchstones. The small cone of Rakata, at the base of Krakatoa, consists of basaltic lavas, which are in part chrysolitic. The formation of the ejected pumice from the pitchstone, on which the author had previously thrown much light, is the subject of further remarks and explanations. He speaks of the glass as being in a state of strain, as is proved by its depolarizing light, and this is mentioned as the cause of its extreme brittleness, in consequence of which it easily crumbles to the finest dust. The rocks are shown to have varied much in liquidity, although having little difference in mineral constitution; and this is attributed to the amount of water they contain. Professor Judd further observes that with water present and therefore a low fusion point, there is less chance of devitrification in a liquid lava; whereas without water and a consequent high fusion point, crystallization of minerals or lapidification is likely to take place in the mass as cooling makes progress; and thus from lavas of the same constitution, under the one difference of amount of water, rocks of very unlike aspect may result.

4. *Microscopical Physiography of the Rock-making Minerals and aid to the microscopical study of rocks*, by H. Rosenbusch. Translated and abridged for use in schools and colleges by Joseph P. Iddings. 333 pp. 8vo, with 26 plates of microphotographs, New York, 1888. (John Wiley & Sons). The thanks of our English-speaking students of Petrography are due to Mr. Iddings for the excellent manner in which he has presented to them the work of Prof. Rosenbusch. The value of this work is much too

well known to make it need commendation here, and the English form that it has now taken is all the more serviceable because of the wise abridgment which it has received, while all that is essential has been retained. The translation is faithful and accurate but sometimes follows the German idiom more closely than is necessary. We may now hope to have instruction in this subject extended among a much larger number of students than has hitherto been possible. The publishers deserve praise for the good appearance which the volume presents and especially for their enterprise in securing copies of the beautiful plates which form so important a part of the German work.

5. *Phenacite in New England*, by GEO. F. KUNZ. (Communicated).—In the September number of this Journal, page 222, the finding of phenacite and topaz near Stoneham, Me., is announced; the locality should have been on Bald Mountain, North Chatham, N. H. Both towns are on the Maine and New Hampshire state line, hence the error now corrected. Another pocket has been found, so that in all over fifty crystals of phenacite and topaz have been procured.

III. BOTANY.

1. *Color-granules in flowers and fruits.*—With the improved optical appliances and better staining agents employed in recent years the coloring matters of plants have received renewed attention. The last contribution on the subject is a paper by COURCHET, [Ann. Sc. nat. sér. VII, pp. 263-374, pl. 6] which confirms certain statements made, with some hesitation, in a review published in this Journal during the current year. Courchet's work appears to have been conducted in a careful manner under the supervision of Flahault at Montpelier, and with abundant material. It is therefore satisfactory to note that it strengthens in all essential particulars the position taken by Schimper, to which reference will soon be made. In view of the importance and the general interest of the subject, it seems proper to give an account of the additions which Courchet has made to our knowledge, and to re-examine briefly the whole matter.

The earlier investigators made out clearly that the coloring substances in leaves, flowers and fruits were of the following kinds: (1) colored cell-sap; (2) protoplasmic bodies or color-granules, containing pigments of various kinds; (3) crystals; (4) pseudo-crystalline forms and amorphous masses. Attempts were made by *Unger* (1846), *Mohl* (1851), *Trécul* (1858), and *Weiss* (1864), to determine the morphology of these structures, but with comparatively little success. Trécul described the facts with accuracy, and for the most part with clearness, but he gave an undue degree of prominence to his theory of vesicular formations, thus diminishing the value of his work. Weiss stated that the color-granules appeared to arise in two ways, (1) by free formation from the general mass of protoplasm, and (2) by the

modification of chlorophyll-granules. In 1872 *Kraus* added some observations regarding ordinary spindle-shaped forms, and stated that they appeared to come from the breaking down of the protein color-granules, but this view was opposed by the fact that these bodies occur even in some very young parts. *Millardet* (1876) by an examination of the coloring matters in the fruit of the tomato, made out some of the relations existing in many cases between chlorophyll-grains and color-granules. It was shown by him that these could change into one another under certain circumstances, and that they possibly had a common origin. This link was partly supplied in 1880, by *Schimper*, who announced the discovery in certain cells containing starch, of colorless granules, which had the function of collecting from the nutrient cell-sap the materials for the construction of starch grains. These bodies were termed by him starch-formers. After pointing out their occurrence and indicating the precautions necessary for their detection, he hints that they have close relations to the other living proteid granules in the vegetable cell. Soon after this, several investigators took the subject up, notably *Meyer*, while Schimper himself made a most important advance. This step consisted in coördinating all the granular living proteid granules, holding that color-granules and chlorophyll-granules are derived from the colorless granules found in the cells at the growing points of plants. For these bodies the common appellation of plastids or plasts was proposed, with the distinctive prefixes, leuco-, chloro-, and chromo-. About this time, or a little before, Van Tieghem suggested the term leucites for the same thing. Although Schimper's terms have been generally adopted, Courchet prefers Van Tieghem's. Schimper teaches that these plasts arise from pre-existing plasts, and that they assume the special form of leucoplasts, chloroplasts, or chromoplasts, according to the office of the part and the conditions under which they are developed. The morphological interest attaching to the organs of a plant is greatly heightened, when it is seen that in the cells themselves which constitute them, there are adaptations not merely in form but in the granular differentiations of the living matter. Just as a foliar expansion can be turned to account by the plant in many different ways, as a foliage-leaf, as a tendril, as a fly-trap, as a thorn, or as a pitcher, so can these simple proteid granules undergo modifications adapting them to the most diverse kinds of work. From the point of view of evolution the subject is of great importance, clearing up some serious difficulties in the way of explaining the adaptation of colors in flowers and fruits to the visits of insects and of birds. The diversified shapes of foliar and floral organs have been rather easier to understand than the marvellous range of useful colors in these parts of the plant, but it is now apparent that all of them may arise from the very simplest starting point common to all.

In all important features, Courchet confirms Schimper's views, and they may be considered as in the main firmly established.

The matter is one of those, which, like the continuity of protoplasm throughout the plant, commands from its coördinating power general acceptance, and should therefore be most carefully examined and reëxamined to ensure complete accuracy of details.

Courchet's special results may be briefly stated as follows:— Chromoplasts are always formed at the expense of chloroplasts or leucoplasts and can give rise at their periphery to crystals or crystalloids. The pigment is produced in many ways, and assumes very diverse characters. The form of the pigment masses is not related to the color, but depends upon its chemical constitution and the matters with which they are combined. Blue, violet and rose tints are generally due to colored cell-sap, although blue pigments are sometimes in the form of crystals or granules which have no relation to the plastids. The orange tints are chiefly due to crystals, or solid masses, and the same is true of most of the yellow tints. Chromoplasts always have a protein stroma combined with the pigment, which latter may be in such fine particles as to give an homogeneous appearance to the whole. The pigment may crystallize out of the granule, and present an appearance as if it is quite independent of it, and it may assume the most diversified shapes. The pigment may, under certain conditions, behave exactly like coloring matters found in other parts of the plant, but whether these matters are produced from the green pigment of the chloroplasts or from derivatives built up in those granules it is, as yet, impossible to determine. It is easy, however, to distinguish two types of coloring matters in the plastids: (1) yellow, always amorphous, much more soluble in alcohol than in chloroform and ether, turning blue with concentrated sulphuric acid, taking on an intermediate green tinge; (2) orange, more soluble in ether and chloroform than in alcohol, turning blue with concentrated sulphuric acid, taking on first a violet-red or violet tinge.

Coloring matters in cell-sap do not as a rule turn blue under the action of concentrated sulphuric acid. G. L. G.

IV. Miscellaneous Scientific Intelligence.

1. *Note on the work of the American Eclipse Expedition to Japan*, 1887; by David P. Todd, Astronomer in charge.—In my preliminary report it was stated that the volunteer observers, working under instructions prepared by me and printed and distributed through the coöperation of the Japanese government, had been moderately successful. Just how successful, it was not possible to ascertain before leaving Japan. But within a few weeks, I have received through our Department of State, a large MS. volume of about seventy drawings of the corona. These are now in process of discussion on a novel system, and are likely to make a trusty contribution to optical coronagraphy.

Also, through the same channel, came a valuable series of observations of the simple duration of total eclipse, at points just

inside the limits of the shadow-path. Of these there are about one hundred independent determinations. When the geographic positions of the observers have been accurately determined, and the observations fully reduced, accurate corrections to the lunar orbit-elements will result, for the epoch in question. The work of the main party in my charge, at Shirakawa, concludes rather less favorably than I had expected, clouds having interfered to such an extent that less than half of the pictures taken with the photo-heliograph are measurable.

The foregoing results of the volunteer work comprise thus the most important astronomical contribution of the Japan Expedition; and are so encouraging that, under the auspices of the Bache trustees, I have taken steps necessary to secure like observations in our western states and British America during the eclipse of the 1st of January next.

But the total outcome of the Japan Expedition fortunately comprises important work besides astronomy. Dr. Holland, who at his own charges accompanied the expedition as naturalist, has enumerated the bulk of his collections, botanical and entomological, in the preliminary report. Under his direction, the final discussion of this valuable material is rapidly progressing. On the present plan, four papers will result: (*a*) list of the phænogamous plants collected by the Expedition; (*b*) list of *Coleoptera* collected by the Expedition, together with descriptions of some apparently new species (with the colaboration of Mr. C. O. Waterhouse of the British Museum); (*c*) list of the *Macrolepidoptera* collected by the Expedition, together with descriptions of new species and notes upon their habits; (*d*) a monograph of the *deltoid* and *pyralid* moths of Japan.

Of these the most significant is the last, in which Dr. Holland will include a full discussion of the unique and extensive collections of the late Mr. Pryer of Yokohama, the result of his labors during a long series of years. Some months are necessary to complete this monograph.

2. *National Academy of Sciences.*—The following papers were entered to be read at the November Meeting, 1888, in New Haven.

E. S. Holden: The Lunar Eclipse, July 22, 1888.

Lewis Boss: The Zone Undertaking of the Astronomische Gesellschaft.

Elias Loomis: The Rain-fall of the North Atlantic Ocean.

W. H. Brewer: A finished Breed of Horses.

Wolcott Gibbs and Hobart Emory Hare: A Systematic Study of the action of definitely related Chemical Compounds upon Animals.

J. S. Newberry: The Cretaceous Flora of North America; On the Zoological Relations of some Paleozoic Fishes.

Henry F. Osborn: The Evolution of the Mammalian Molar Teeth to and from the Tritubercular Type.

L. A. Lee: Some scientific results of the Albatross Expedition from Washington to San Francisco.

A. A. Michelson and E. W. Morley: Some measurements of relative Wave-lengths.

E. S. Dana: A new mineral from Maine.

C. H. F. PETERS: Remarks on the expression of the Law of Attraction in the Stellar Systems.

A. HALL: Note on the Satellite of Neptune.

G. K. GILBERT: The Problem of Soaring Birds.

J. W. POWELL: The Laws of Corrasion.

3. *Note to Article VIII, in this volume, by the Author.*—In mentioning the dredging at Sandwich, in the July number of this Journal (p. 56), I did not expect to give the subject further attention. I have since become satisfied, after visits to the place named and extended inquiry, that no Tertiary beds have been opened there. The supposed "find" has proved a disappointment. There is too little information about it available to justify attaching any importance to it. The borings made along the line of the proposed canal give no reason to expect that fossiliferous deposits will be touched hereafter in the progress of the work. W. W. DODGE.

4. *Tuckerman Memorial Library.*—The large collection of books and papers relating to Lichens, made by the late Prof. Edward Tuckerman, has been presented by Mrs. Tuckerman, in accordance with his own wish, to Amherst College Library. It is desired to make this "Tuckerman Memorial Library" as complete as possible and the librarian, Mr. William I. Fletcher, invites contributions in money or in material to this end. The money contributed will be kept as a fund of which only the income will be employed in making additions to the collection, or in making repairs to the binding. The sum of $1000 would probably suffice as such a fund.

A Manual of the Vertebrate Animals of the Northern United States, by David Starr Jordan, President of the University of Indiana, 5th edit., entirely rewritten and much enlarged, 376 pp., 12mo, Chicago, 1888. (A. McClurg & Co.) In this new edition of the Manual all marine species are included; the geographical limits have been extended so as to include Canada, Minnesota, Iowa and Missouri; and the arrangement has been changed, and other improvements introduced.

Catalogue of Fossil Reptilia and Amphibia of the British Museum. Part I, containing the Orders Ornithosauria, Crocodilia, Dinosauria, Squamata, Rhynchocephalia and Proterosauria, by Richard Lyddeker, B.A., F.G.S., etc. 310 pp. 8vo. London, 1888.

Cincinnati Observatory. Zone Catalogue of 4050 stars for the epoch of 1885, by J. G. Porter, astronomer. Cincinnati, 1887.

Old and New Astronomy, by R. A. Proctor. (Longmans, Green & Co., London and New York.)

Transactions of the American Philosopical Society, Vol. XVI, Part II, contains papers by E. D. Cope on the intercentrum of terrestrial vertebrata, systematic catalogue of the Permian vertebrata of N. America, Synopsis of the Vertebrate Fauna of the Puerco series, the shoulder, girdle and extremities of Eryops, and by H. C. DeS. Abbot, on a chemical study of *Yucca angustifolia.*

Centennial volume of the Memoirs of the American Academy of Arts and Sciences, Vol. XI, Part VI, No. vii. 200 pp. 4to. Occupied with a Memoir of Daniel Treadwell by Morrill Wyman, M.D.

Die Geoideformationen der Eiszeit, von Erich von Drygalski, Dr. Phil. (Ges. d. Erdk. Berlin, xxii, 3, 4,) Berlin, 1887.

Annotated Catalogue of the species of Porites and Synaræa in the U. S. National Museum, with figures, and a description of a new species, by Richard Rathbun, Proc. U. S. Nat. Mus., 1887.

5. *Communication on the American Report of the International Congress of Geologists*, by J. W. POWELL, Director of the U. S. Geological Survey; addressed to the Editor of this Journal under date of Washington, D. C., Nov. 23, 1888.*—The American report presented to the International Congress of Geologists at the meeting in London commencing September 17, 1888, has been received, and I find that my name is attached to it in several places in such a manner that I am made to appear as one of the parties responsible for its preparation and agreeing to it. This is an unfair and improper use of my name. I was for much of the time a member of the committee, but when it became manifest that some of its members were determined to submit a report in general character similar to the one finally submitted, I resigned from the committee, preferring so to do rather than prepare a dissenting report. Without entering into detail, lest this communication be made very long, I beg to present my general reasons for not wishing to be considered as in any way subscribing to the report.

The subject matter of the report is not of such a nature that a deliberative body can properly determine it by vote. Facts of observation, and generalizations therefrom, are proper subjects for discussion, but they should not be submitted to decision by vote. In my judgment this principle is fundamental.

At some of the meetings I was represented by a delegate; and at some of the meetings I was present. Through my representative and personally myself, I endeavored to induce the committee to consider questions of geologic technics, such as a color scheme and a fundamental taxonomic time scheme necessary to the use of a color scheme; and I endeavored to have principles of geologic nomenclature formulated, etc. I protested, in season, and perhaps out of season, against pursuing such a course as to make the committee a debating club on geologic theories and on the verity of geologic discoveries.

The assembling of a large number of geologists from various portions of the world, all more or less engaged in active research, furnishes a valuable opportunity for the presentation of papers, for the interchange of opinions, and for the enlargement of the scientific horizon of the several members. The questions that arise in this manner are to be decided ultimately only by the light of science, and no weight should be given to any man's statement or generalization other than that inherent in the facts themselves. For a deliberative body to determine or settle any such question, or in any way to make authoritative annunciation of facts and principles, is at variance with sound scientific procedure and wholly vicious.

On the other hand, geologic language is conventional, as all language is conventional, and all geologic conventions, whether

* Received too late for earlier insertion.—EDS.

they are in words, in colors, or in graphic forms, can be established by agreement with propriety, and perhaps with advantage to the science.

There is no body of men so wise or so powerful that it can establish the science of geology by authority, and it is pretentious and unseemly to make the attempt; and to authoritatively announce a fact or generalization in science and ask its acceptance is an absurdity. Any number or body of geologists may properly agree to use a common system of representation, and may properly recommend others to use the same.

In view of these considerations, I urged upon the committee questions of conventions, as I greatly desired that the American committee should formulate American opinions upon these subjects.

The papers which appear in the report were not presented to the committee in a finished form, while I was present, but most of them merely in abstract, and the reporters finally published what they severally desired. I believe that the one prepared by Professor Williams on the Devonian formations of North America, is in form and substance of such a nature as to elucidate some of the principles which should guide in the preparation of geologic conventions. The paper which I prepared was brief, but was, I thought, pertinent to the subject in hand; but evidently it did not meet with the approval of the committee, for other reporters included the consideration of the Quaternary formations in their papers, that is, the members of the committee were determined that the Quaternary formations should be discussed in such a manner as to exhibit a supposed best classification, or at least such a one as they would recommend, all of which required a review of the general subject of the Quaternary formations of the country, and the more or less final settlement of many problems yet under discussion. Seeing that the report prepared by myself was, like that of Professor Williams, upon a general theory of precedure different from that held by most of the persons who were present at the meetings of the committee, I withdrew it at the time I resigned from the committee, and another member was appointed who prepared a paper more in harmony with the general views.

With regard to the papers which were actually published, that of Professor Williams is in harmony with my conclusions, and, I believe, germane to the purpose for which the committee was organized. The other papers are not germane to the proper function of the committee as understood by myself. To many of the opinions expressed I can agree, to many others I cannot, but to none of the papers is it proper that I should sign my name, because I am not the author of any one or part of one.

It will be noticed on examining the papers that a number of taxonomic schemes are presented. None of them are such as I would use, were I engaged in making a survey on the ground; and, futhermore, none of them are used by members of the United

States Geological Survey. It is, therefore, manifestly absurd that my name should be employed in their support, and that I should thus be made virtually to condemn the work of all of my assistants actually engaged in works of survey throughout the United States.

Long experience and careful consideration of this subject have led me to the conclusion that no detailed taxonomic scheme can be adopted for the entire country; but that there are many geologic provinces, and that in each one a distinct taxonomic scheme is necessary in order properly to present the facts exhibited in nature. On the other hand, I believe that a general time scale can be adopted to which the taxonomic schemes of the several geologic provinces can be referred with greater or less certainty. The general classification of the formations of each geologic province must be constructed and reconstructed with the course of investigation, and it should not be hampered with preconceived classifications; but geologists may well be furnished with a purely artificial or conventional time scheme to be used in the progress of their work.

A system of geologic conventions in common usage throughout the world seems to be desirable for two potent reasons: first, geologists will be able thus to understand one another's work with a great saving of labor and time; and second, a common language of geology will make the science available to a much larger number of people, and its beauties and truths may soon become the common property of all educated people. But how shall a universal system of conventions be established? If by direct agreement through a congress of the world's active workers in geology, it may be a compromise and may not be the very best. On the other hand, any good universal system is better than the multiform systems now in use. To be established as a general system, it must meet with very general if not universal acceptance, and no system should be promulgated which has a large number of opponents, lest it add to the confusion.

There is another method by which a general system may be secured. Geologists may go on devising, amending, and improving their systems severally, each new worker adopting such a system as he may think best; until at last, by a course of intelligent selection, a common system is evolved. A system evolved in this manner can be reached only in the distant future, and in the meantime the disadvantages of diverse systems will retard investigation and keep the science more or less buried from the general public under a cloud of conventions. Whether a system shall be formulated by enactment or evolved by practice is a question worthy of consideration. The legislative method may be tried, and if it fails the judicial method remains.

The following is the abstract of my report to the committee.—The full report was never completed.

The Quaternary or Pleistocene period is represented by all those

rocks which have been formed since the beginning of the glacial epoch. As thus defined they will probably include some rocks which have been called Pliocene.

The theory of the fundamental or principal classification of these rocks which has actually obtained in the world differs materially from that of the classification of all other clastic formations; as they are primarly classed by agencies and conditions of genesis.

Progress has been made in classifying the glacial deposits chronologically, and in classifying some of the lacustrine and marine pleistocene deposits chronologically by correlating them with the glacial epochs, or by a study of their fossils; but it is worthy of emphasis that the fundamental classification of all the rocks of this period is one based on genesis.

The series of geological events that constitute the history of the glacial epoch in North America are exceedingly varied and interesting. The great ice sheet that advanced from polar regions into middle latitudes, and then retreated and again advanced and retreated, was a dominant geological agency, and about its history all other phenomena are grouped. These phenomena are found in the records of a great number of lakes, many of which have disappeared, and in marine deposits which mark the sites of old shores and which are intimately related to the glacial deposits. In the Mississippi Valley the deposits of loess extend nearly to the Gulf of Mexico, and these formations are probably in part of glacial origin, and they have many intimate relations with the deposits wholly glacial. The deformations of the surface by diastrophic agencies through the glacial period are many and profound, and their history is recorded in a variety of base-level formations. When these facts are all recorded a history of the glacial period can be constructed which will be of profound importance as an integral chapter in the history of the earth, the principles of which will be extended to all the chapters of the volume. In northern latitudes glacial phenomena prevail. In southern latitudes many other phenomena can be correlated in time with glacial facts, because glacial action was projected far southward along mountain ranges and about isolated mountains, and because the glacial sediments of the Atlantic coast extend far southward and their histories are interwoven with the history of the sediments derived from more southern rivers and shores; and finally, because glacier-prepared sediment was carried into the valley of the Mississippi and spread far toward the Gulf.

The classes usually recognized in practice by geologists of this country are as follows:

1. Formations of fluviatile origin, otherwise called "flood-plain deposits," or alluvial deposits.
2. Formations of lacustrine origin, or lake deposits.
3. Formations of oceanic origin, or marine deposits along shore.
4. Formations due to the agency of torrents, a large part of which have been called alluvial fans or alluvial cones.

5. Formations of eolian origin, as sand-dunes.

6. Formations in swamps and marshes, as peat-bogs.

7. Formations in deltas, which are in part fluviatile and in part marine or lacustrine.

8. Formations of glacial origin.

9. Formations usually designated as Loess, which by some have been considered eolian ; but later investigations seem to show that Loess is formed in part, at least, of glacier-ground rock-flour deposited in quiet waters.

10. Formations called soils and sub-soils, which cover the greater part of the surface of the land.

The Quaternary formations have proved to be of prime importance, because the principles of geology derived from their investigation constitute a large body of the doctrines applied in the study of the older formations. The rocks are also of great interest, and have been and will be studied in great detail, because of their industrial importance, and because, being at the surface, they are open to view, and ever present questions of interest even to the passing observer.

These formations represent a period or constitute a system in the proper sense of that term ; and the period is distinguished from all others because the formations are classified on a distinct basis, because they overlie all other formations and cover the entire extent of lands, and because the general principles of geology are mainly derived from their study.

All of the great genetic classes which have been mentioned, except, perhaps, the Loess, have been divided into subordinate parts, for each one of which some conventional sign is necessary in the preparation of Quaternary charts. It will thus be seen that a special system is necessary for their representation.

Yet another fact must be considered in this connection. The Quaternary formations cover, to a greater or less extent, all other formations ; and the chart designed to represent the distribution of older formations cannot be used to represent the Quaternary formations without imposing one system of conventional symbols upon another. The attempts to do this have not been generally successful, and it has been and will be found that special Quaternary maps are necessary, and a system of cartographic conventions must be devised for this purpose also.

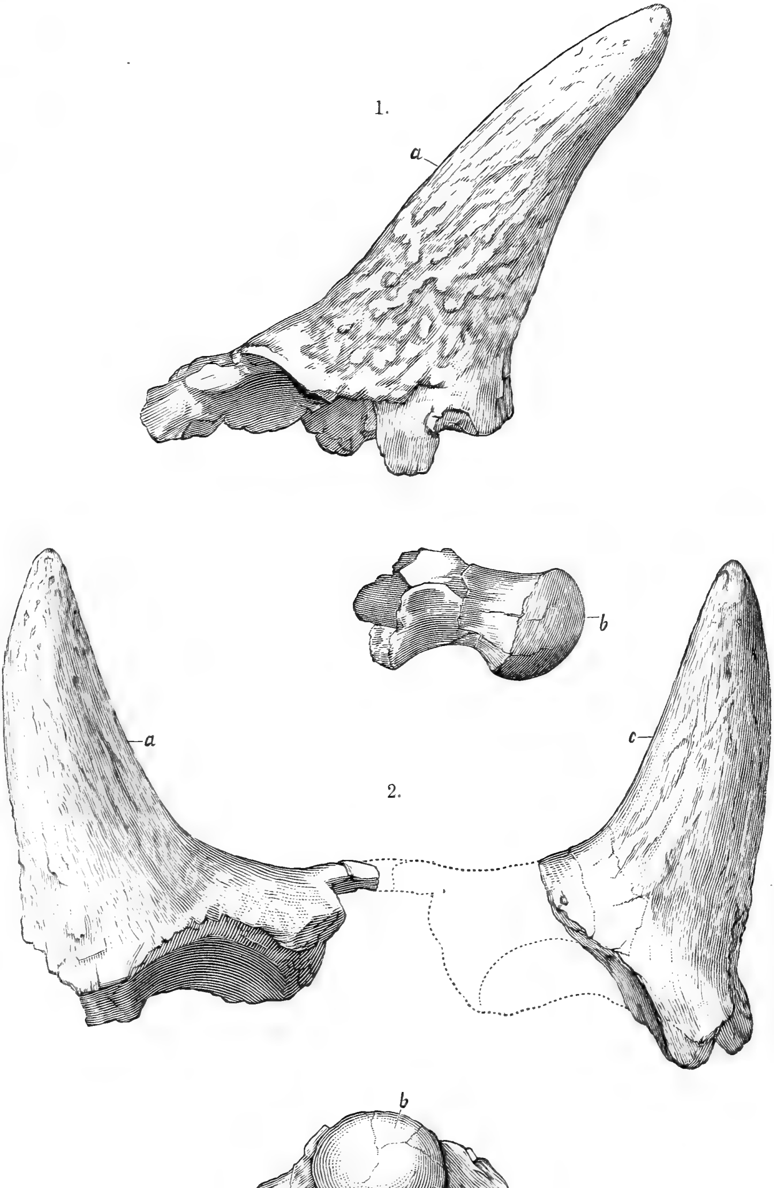
The conclusions reached in the foregoing statements are as follows:

1. The Quaternary or Pleistocene formations represent a distinct period or system.

2. The Quaternary period should be defined as beginning with the glacial epoch.

3. The Quaternary formations are fundamentally classified by agency and condition of origin.

4. A cartographic scheme is necessary for the representation of Quaternary formations.



CERATOPS MONTANUS, Marsh. One-fourth natural size.

APPENDIX.

ART. L.—*A New Family of Horned Dinosauria, from the Cretaceous;* by O. C. MARSH. (With Plate XI.)

DURING the past season, a special effort has been made by one field-party of the U. S. Geological Survey, to explore the Laramie formation, more particularly in Dakota and Montana. In this work, important collections of vertebrate fossils have been secured, and among them are remains of some new Dinosaurs of much interest, one of which is briefly described below.

Ceratops montanus, gen. et sp. nov.

The present genus appears to be nearly allied to *Stegosaurus* of the Jurassic, but differs especially in having had a pair of large horns on the upper part of the head. These were supported by massive horn-cores firmly coössified with the occipital crest. The latter are probably attached to the parietal bones, but, as the sutures in this region are obliterated, they may be supported in part by the squamosals.

The horn-cores in the type specimen are sub-triangular at base, but nearly round in section in the upper half. Their position is represented approximately in the figures of the accompanying plate. These horn-cores are slightly hollowed at the base, but are otherwise solid. The exterior texture and markings show that they were evidently covered with true horns, and these must have formed large and powerful offensive weapons.

In position and direction, these horn-cores are somewhat similar to the large posterior pair of protuberances in *Meiolania*, one of the extinct *Testudinata*, and to the corresponding ones of the existing *Phrynosoma*. The only known example of similar structure in the *Dinosauria* is the single median horn-core on the nasals of *Ceratosaurus*, from the Jurassic. It is not improbable that there were other horn-cores on the skull in the present genus, but, of this, there is at present no positive evidence. A detached median prominence resembling a horn-core was found with some similar remains, but may pertain to an allied genus.

The resemblance in form and position of the posterior horn-cores to those of some of the ungulate mammals is very striking, and, if detached, they would naturally be referred to that group.

The basioccipital found in place with these horn-cores, and represented in plate XI (figures 1 and 2, *b*), is much elongated, and formed the entire occipital condyle. Its exact position with reference to the horn-cores could not be determined.

Teeth, vertebræ, and limb bones which probably belong to the present genus were all secured in the same horizon. They indicate a close affinity with *Stegosaurus*, which was probably the Jurassic ancestor of *Ceratops*.

Among other remains referred to the present reptile, but not found with the type specimen, are some peculiar, large dermal plates, in pairs, that indicate a well-ossified armor. These plates show indications of being covered, in part at least, with scutes, as in turtles. Their position cannot at present be determined.

The type specimen on which the present genus and species are based was found in place, in the Laramie deposits of the Cretaceous, in Montana, by Mr. J. B. Hatcher, of the U. S. Geological Survey. Other specimens apparently pertaining to the same species were secured in the same horizon of the same region.

Remains of the same reptile, or one nearly allied, had previously been found in Colorado, in deposits of about the same age, by Mr. G. H. Eldridge, also of the U. S. Geological Survey.

The associated fossils found with the present specimens are remains of other Dinosaurs, crocodiles, turtles, and fishes, mostly of Cretaceous types. The mollusks in the same beds indicate fresh-water deposits.

The fossils here described indicate a reptile of large size, twenty-five or thirty feet in length, and of massive proportions. With its horned head and peculiar dermal armor, it must have presented in life a very strange appearance.

The remains at present referred to this genus, while resembling *Stegosaurus* in various important characters, appear to represent a distinct and highly specialized family, that may be called the *Ceratopsidæ*. They will be described more fully in a later number of this Journal.

Yale College, New Haven, Conn., November 23, 1888.

Explanation of Plate XI.

Figure 1.—Horn-core and basioccipital of *Ceratops montanus*, Marsh; side view. *a*, horn-core; *b*, basioccipital.

Figure 2.—Horn-cores and basioccipital of same skull; posterior view. *a*, left horn-core; *b*, basioccipital; *c*, right horn-core.

Both figures are one-fourth natural size.

INDEX TO VOLUME XXXVI.*

* This Index contains the general heads BOTANY, CHEMISTRY, GEOLOGY, MINERALS, OBITUARY, ROCKS, ZOOLOGY, and under each the titles of Articles referring thereto are mentioned.

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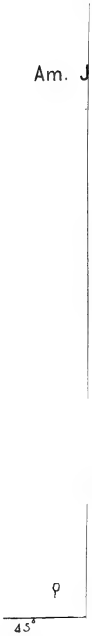
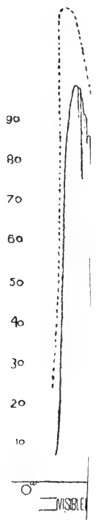




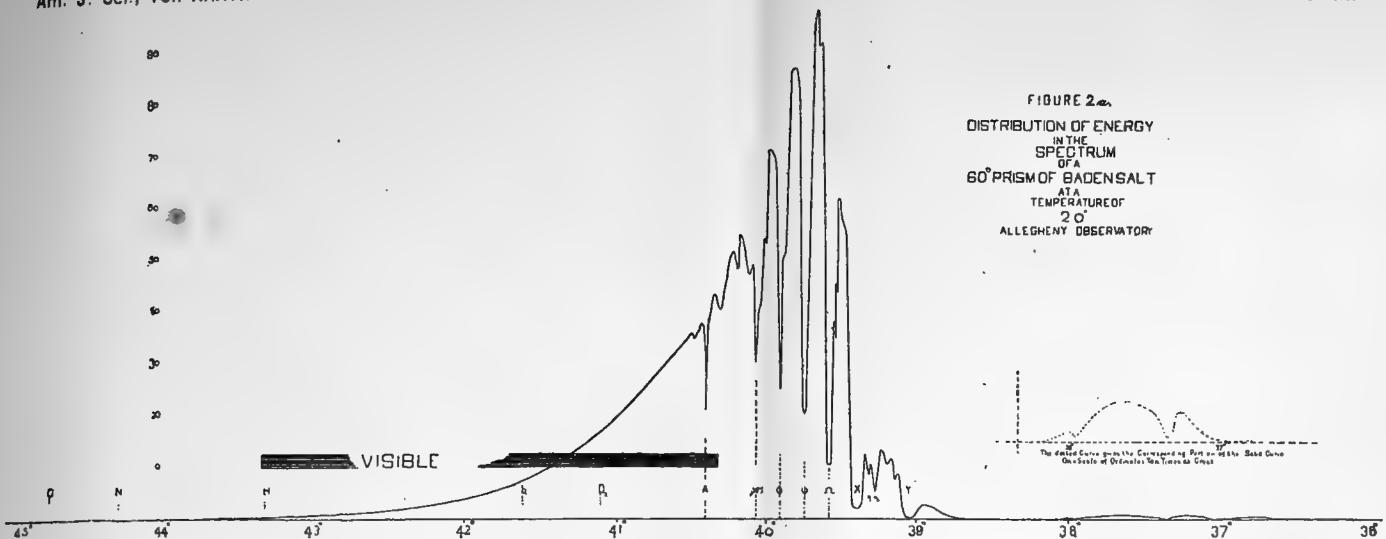
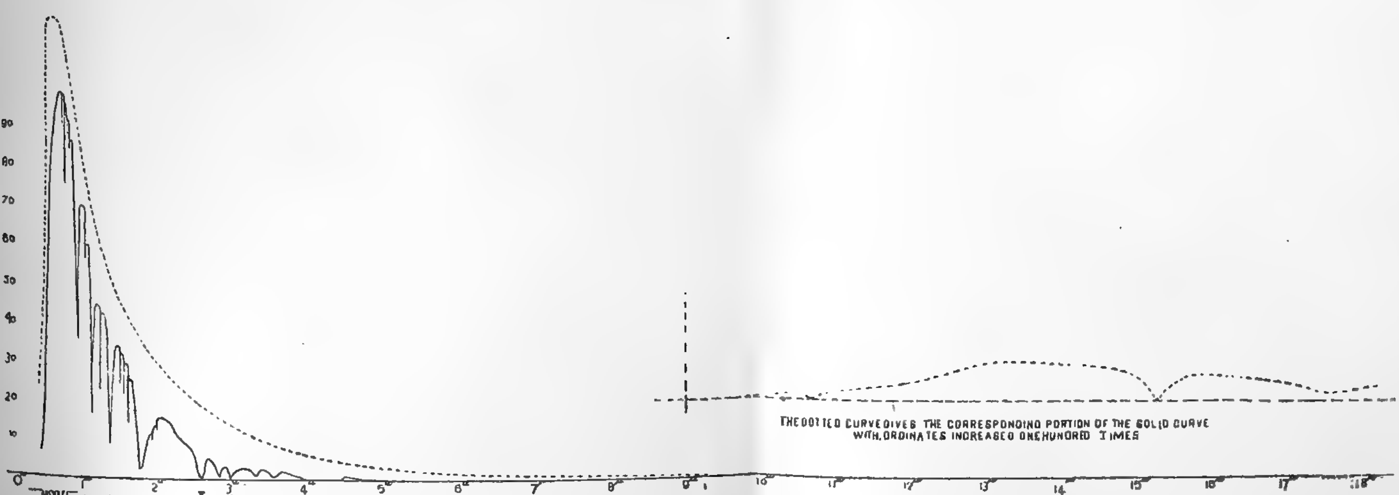


FIGURE 2a.
DISTRIBUTION OF ENERGY IN THE SPECTRUM OF A 60° PRISM OF BADEN SALT AT A TEMPERATURE OF 20°
ALLEGHENY OBSERVATORY



NORMAL ENERGY SPECTRUM
FIGURE 2 b

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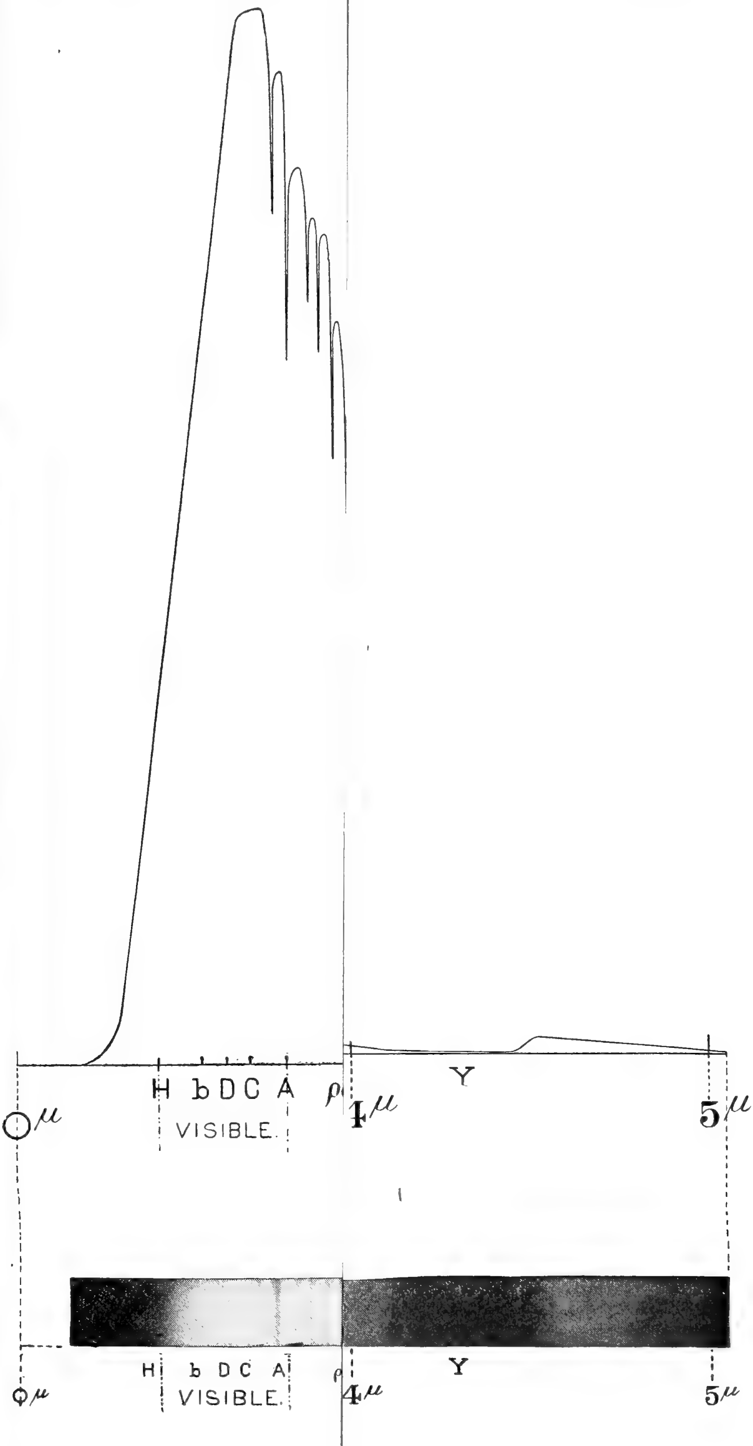
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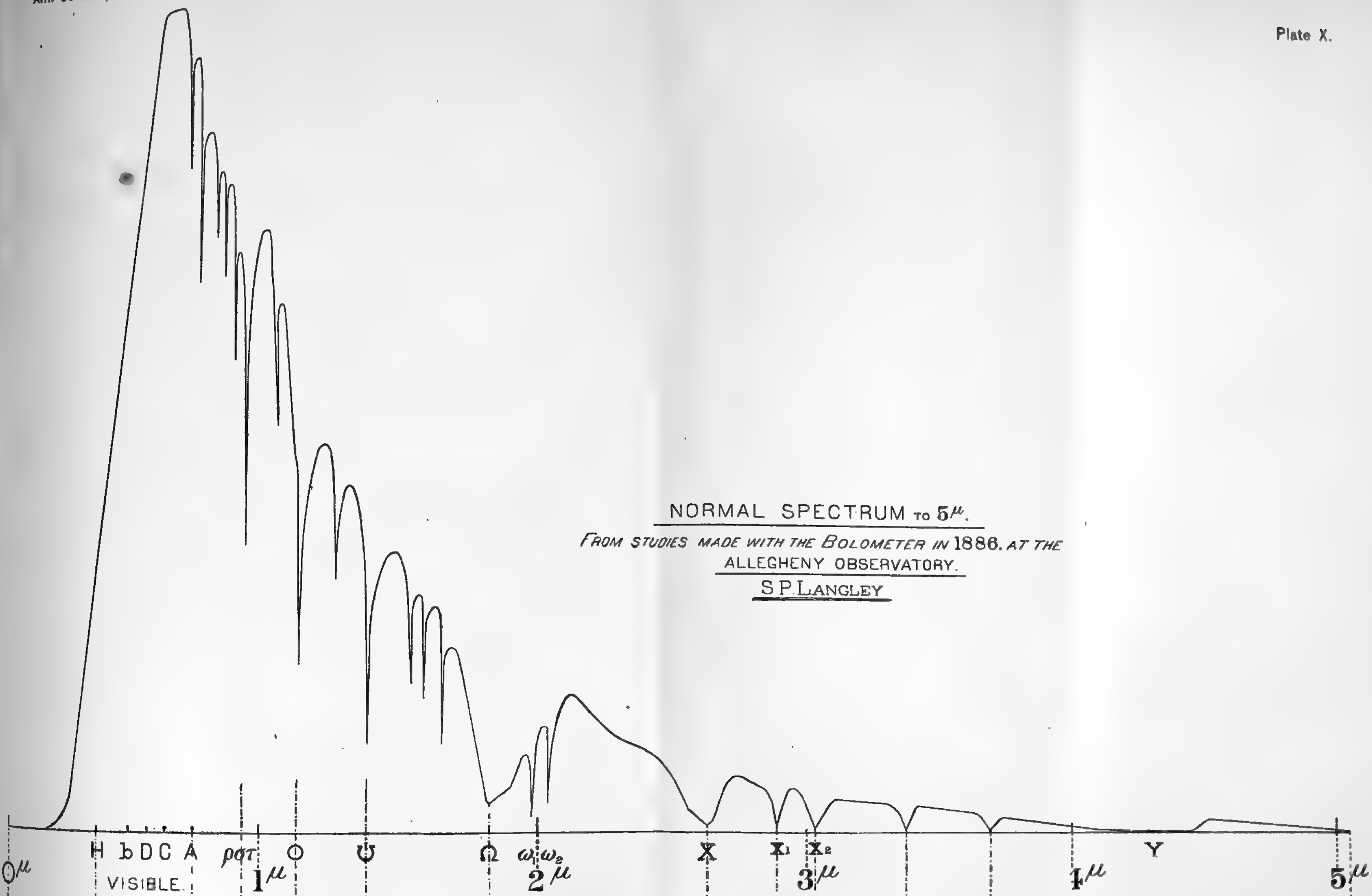

FIGURE 3a.

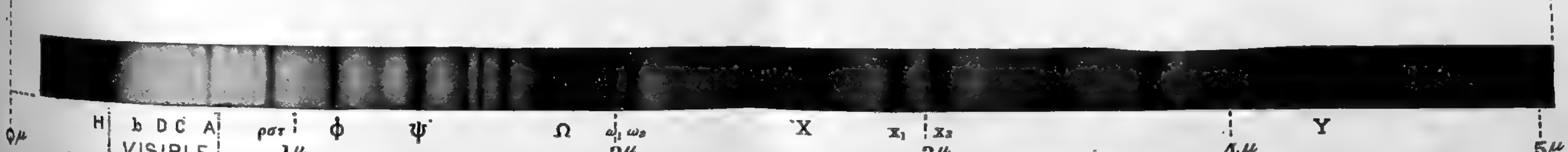

FIGURE 3b.

APPENDIX.

I. LIST OF THE WRITINGS

OF

DR. ASA GRAY.

CHRONOLOGICALLY ARRANGED.*

I. Scientific Works and Articles.

1834.

A Sketch of the Mineralogy of a portion of Jefferson and St. Lawrence Counties, (N. Y.); by Drs. J. B. Crawe, of Watertown, and A. Gray, of Utica, (N. Y.). Am. J. Sci., xxv, 346–350.

North American Gramineæ and Cyperaceæ (exsiccatæ). Part I, 1834; Part II, 1835.

1835.

A Monograph of the N. American species of Rhynchospora. Ann. N. Y. Lyc., III, 191–220 (reprint, 191–219), t. 1. [Hook. Comp. Bot. Mag., II, 26–38.]

A notice of some new, rare, and otherwise interesting plants from the northern and western portions of the State of New York. Ann. N. Y. Lyc., III, 221–238 (reprint, 220–236).

1836.

Elements of Botany. New York, 1836, 8vo, pp. xiv, 428.

1837.

Remarks on the structure and affinities of the order Ceratophyllaceæ. Ann. N. Y. Lyc., IV, 41–60.

Melanthacearum Americæ Septentrionalis Revisio. Ann. N. Y. Lyc., IV, 105–140.

Remarks on the progress of discovery relative to vegetable fecundation: being a preface to the translation of A. J. C. Corda's "Beiträge zur Lehre von der Befruchtung der Pflanzen." Am. J. Sci., XXXI, 308–317.

1838.

A Flora of North America: containing abridged descriptions of all the known indigenous and naturalized Plants growing north of Mexico; arranged according to the Natural System. By John Torrey and Asa Gray. Vol. I. New York, 1838–1840, 8vo, pp. xvi, 711.—Vol. II. 1841–1843, pp. 504.

* In the preparation of this list Dr. S. Watson and the undersigned have received much assistance from Professors Farlow and C. S. Sargent. A great part of the collection and revision of references has been done by Mr. W. F. Ganong, Assistant in Botany. Although much care has been exercised in the elaboration of the list, there are doubtless some omissions. In view of rendering the list more nearly complete, correspondents are urged to forward promptly any corrections.

This list will be followed by an index to the writings. G. L. G.

1840.

Remarks chiefly on the Synonymy of several North American plants of the Orchis tribe. Am. J. Sci., XXXVIII, 306–311.

1841.

Notices of European Herbaria, particularly those most interesting to the North American Botanist. Am. J. Sci., XL, 1–18. [Ann. Nat. Hist., VII, 132–140, 179–185; Hooker's Journ. Bot., III, 353–374.]

Notice of the Botanical Writings of the late C. S. Rafinesque. Am. J. Sci., XL, 221–241.

1842.

Notes of a botanical excursion to the mountains of North Carolina, etc., with some remarks on the botany of the higher Alleghany Mountains. Am. J. Sci., XLII, 1–49. [Hook. Lond. Journ. Bot., I, 1–14, 217–237; II, 113–125: III, 230–242.]

The Botanical Text-Book for Colleges, Schools and Private Students. New York. 1842. 8vo, pp. 413. Edition 2d, ib. 1845, 8vo, pp. 509; 3d, ib. 1850, 8vo, pp. 520; 4th, ib. 1853, 8vo, pp. 528; 5th, under the title, Introduction to Structural and Systematic Botany, being a fifth and revised edition of The Botanical Text-Book, New York, 1857–1858, pp. xii, 555. A second issue bears date 1860. Edition 6th, Part I. Structural Botany, or Organography on the basis of Morphology. New York, 1879, 8vo, pp. XII, 442.

1843.

Selections from the Scientific Correspondence of Cadwallader Colden with Gronovius, Linnæus, Collinson and other Naturalists. Am. J. Sci., XLIV, 85–133.

1844.

Characters of some new genera [Monoptilon, Amphipappus, Calliachyris, Anisocoma] and species of plants of the natural order Compositæ, from the Rocky Mountains and Upper California. Proc. Bost. Soc. Nat. Hist., I, 210–212 (abstract); Journ. Bost. Soc. Nat. Hist., V, 104–111, with plate.

The Longevity of Trees. N. A. Review, July, 1844, 189–238.

1845.

The Chemistry of Vegetation. N. A. Review, Jan., 1845, 3–42.

Plantæ Lindheimerianæ: an enumeration of F. Lindheimer's collection of Texan plants, with remarks, and descriptions of new species, etc. By George Engelmann and Asa Gray. Journ. Bost. Soc. Nat. Hist., V, 210–264.

1846.

Musci Alleghanienses, sive Spicilegia Muscorum atque Hepaticarum quos in itinere a Marylandia usqûe ad Georgiam per tractus montium A. D. mdcccxliii decerpserunt Asa Gray et W. S. Sullivant (interjectis nonnullis aliunde collectis). [Review, with notes.] Am. J. Sci., II, I, 70–81, 312.

Notice of a new genus of plants of the order Santalaceæ (Darbya). Am. J. Sci., II, I, 386–389; Proc. Bost. Soc. Nat. Hist., II, 115–116 (abstract); Journ. Bost. Soc. Nat. Hist., V, 348–351.

Scientific Results of the Exploring Expedition. N. A. Review, July, 1846, 211–226.

Analogy between the Flora of Japan and that of the United States. Am. J. Sci., II, II, 135–136.

Characters of some new genera and species of Compositæ from Texas. Proc. Am. Acad., I, 46–50. [Am. J. Sci., II, III, 274–276, in part.]

Chloris Boreali-Americana. Illustrations of new, rare, or otherwise interesting North American Plants, selected chiefly from those recently brought into cultivation at the Botanic Garden of Harvard University. Decade I. Mem. Am. Acad., III, 1–56, tt. 1–10.

1847.

Food of the Mastodon. Am. J. Sci., II, III, 436.

Note upon Carex loliacea, *Linn.* and C. gracilis, *Ehrh.* Am. J. Sci., II, IV, 19–22.

1848.

Genera Floræ Americæ Boreali-Orientalis Illustrata. The Genera of the Plants of the United States illustrated by figures and analyses from nature, by Isaac Sprague, Superintended and with descriptions, etc., by Asa Gray. Vols. I, II (1848, 1849), 8°, pp. 230, 229, and 186 plates.

A Manual of the Botany of the Northern United States, from New England to Wisconsin and South to Ohio and Pennsylvania inclusive (the Mosses and Liverworts by Wm. S. Sullivant), arranged according to the Natural System. Boston and Cambridge, 1848, 8vo, pp. lxxii, 710. [Later editions are given under dates of publication.]

1849.

Plantæ Fendlerianæ Novi-Mexicanæ: an account of a Collection of Plants made chiefly in the Vicinity of Santa Fé, New Mexico, by Augustus Fendler. Proc. Am. Acad., II, 5–9 [abstract]; Mem. Am. Acad., IV, 1–116.

On some plants of the order Compositæ from the Sandwich Islands. Proc. Am. Assoc., II, 397–398.

On the composition of the plant by phytons, and some applications of phyllotaxis. Proc. Am. Assoc., II, 438–444.

Note on the genus Thelesperma, *Lessing.* Hook. Journ. Bot., I, 252.

1850.

Plantæ Lindheimerianæ, Part II. Journ. Bost. Soc. Nat. Hist., VI, 141–233.

1851.

Characters of some Gnaphalioid Compositæ of the division Angiantheæ. Hook. Journ. Bot., III, 97–102, 147–153, 172–178.

Characters of a new genus (Dissothrix) of Compositæ-Eupatoriaceæ, with remarks on some other genera of the same tribe. Hook. Journ. Bot., III, 223–225.

1852.

Account of Argyroxiphium, a remarkable genus of Compositæ, belonging to the mountains of the Sandwich Islands. Proc. Am. Acad., II, 159–160.

Characters of three new genera of plants of the orders Violaceæ and Anonaceæ, discovered by the naturalists of the United States Exploring Expedition [Agatea, Isodendrion, Richella]. Proc. Am. Acad., II, 323–325.

Plantæ Wrightianæ Texano—Neo-Mexicanæ: an account of a Collection of Plants made by Charles Wright, A.M., in an expedition from Texas to El Paso, New Mexico, in the summer and autumn of 1849. Part I. Smithsonian Contributions, III, 1–146, tt. 10.

Remarks on Menodora, Humb. and Bonpl., and Bolivaria, Cham. and Schlecht. Am. J. Sci., II, XIV, 41–45.

Note on Tetratheca. Hook. Journ. Bot., IV, 199–200.

Characters of some Southwest Australian Compositæ, principally of the subtribe Gnaphalieæ. Hook. Journ. Bot., IV, 225–232, 266–276.

1853.

Plantæ Wrightianæ Texano—Neo-Mexicanæ. Part II. An account of a collection of plants made by Charles Wright, A.M., in Western Texas, New Mexico and Sonora, in the years 1851 and 1852. Smithsonian Contributions, V, 1–119, tt. 4.

Brief characters of some new genera and species of Nyctaginaceæ, principally collected in Texas and New Mexico. Am. J. Sci., II, XV, 259–263, 319–324.

On the discovery of two species of Trichomanes in the State of Alabama, one of which is new. Am. J. Sci., II, XV, 324–326.

Characters of Tetraclea, a new genus of Verbenaceæ. Am. J. Sci., II, xvi, 97–98.

Note on the parasitism of Comandra umbellata, Nutt. Am. J. Sci., II, xvi, 250–251. [Ann. Nat. Hist., xii, 365–366.]

Characters of some new genera of Plants, mostly from Polynesia, in the collection of the United States Exploring Expedition under Captain Wilkes. Proc. Am. Acad., III, 48–54, 127–129.

1854.

On the age of the large tree recently felled in California. Am. J. Sci., II, xvii, 440–443.

Note on the genus Buckleya. Am. J. Sci., II, xviii, 98–100.

Plantæ Novæ Thurberianæ: The characters of some New Genera and Species of Plants in a Collection made by George Thurber, Esq., of the late Mexican Boundary Commission, chiefly in New Mexico and Sonora. Mem. Am. Acad., n. s., v, 297–328.

On the Affinities of the Genus Vavæa, Benth.; also of Rhytidandra, Gray. Mem. Am. Acad., n. s., v, 329–336. [Hook. Journ. Bot., vii, 189–190.]

United States Exploring Expedition, during the years 1838, 1839, 1840, 1841, 1842, under the command of Charles Wilkes, U. S. N. Vol. xv. Botany. Phanerogamia. With a folio Atlas of one hundred plates. Part I. Philadelphia, 1854. 4°, pp. 775.

Mammoth Trees of California. Am. J. Sci., II, xviii, 286–287.

1855.

The Smithsonian Institution. Am. J. Sci., II, xx, 1–21.

Botanical Report, by John Torrey and Asa Gray, upon the Collections made by Captain Gunnison, Topographical Engineers, in 1853, and by Lieutenant E. G. Beckwith, Third Artillery, in 1854. Pacific R. R. Surveys, ii 115–132, with ten plates.

Report on the Botany of the Expedition [under Captain John Pope], by John Torrey and Asa Gray. Pacific R. R. Surveys, ii, 157–178, with ten plates.

Note on the Development and Structure of the Integuments of the Seed of Magnolia. Hook. Journ. Bot., vii, 243–245; viii, 26.

1856.

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